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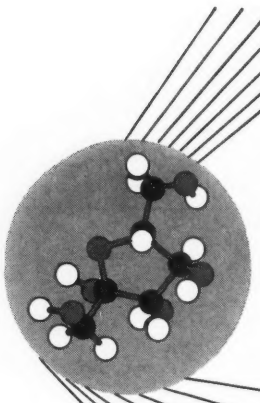

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A Method for Surgical Closure of Interauricular Septal Defects.—Robert E. Gross, Elton Watkins, Jr., Alfred A. Pomeranz, and Edward I. Goldsmith.

(Legend on opposite page.)

SURGERY
GYNECOLOGY AND OBSTETRICS

VOLUME 96 JANUARY, 1953 NUMBER 1

A METHOD FOR SURGICAL CLOSURE OF INTERAURICULAR SEPTAL DEFECTS

ROBERT E. GROSS, M.D., F.A.C.S., ELTON WATKINS, JR., M.D.,
ALFRED A. POMERANZ, M.D., and EDWARD I. GOLDSMITH, M.D.,
Boston, Massachusetts

OPENINGS in the interauricular septum allow shunting of blood from the left to the right atrium, thereby increasing the flow through the right side of the heart and through the pulmonary circulation. Although the condition is frequently encountered as the sole cardiac abnormality, its influence on longevity is poorly documented. In the average run of cases, there seems to be little doubt that a septal defect reduces life expectancy. While there is no direct correlation between the size of a septal opening and the duration of life, in general the smaller defects are known to be compatible with a long and active existence, while the larger openings are very apt to bring about right-sided heart failure or fatality in childhood or early adult years. If possible, it is highly desirable to find some surgical means whereby the larger defects can be closed and cardiac invalidism or fatality thereby be prevented. With careful clinical evaluation and with the use of modern ancillary diagnostic methods, it should be possible to select those humans who have atrial defects of considerable size and who might logically be expected to be in considerable danger from the abnormality. Such patients would constitute a group who should be greatly benefited by an adequate corrective procedure.

Described is a method devised for the closure of interauricular septal defects. Investigations in the Laboratory for Surgical Research have permitted development and perfection of the technique; experiences gained from surgical undertakings in humans indicate that the method is of practical value for treatment of interauricular septal defects in man.

From the Surgical Service of The Children's Hospital and the Department of Surgery, Harvard Medical School.

These investigations were aided by grants from the American Heart Association, Inc., the National Heart Institute of the United States Public Health Service, the Oregon Heart Association, and the Dazian Foundation for Medical Research.

METHODS PREVIOUSLY ADVOCATED FOR CLOSURE OF INTERAURICULAR SEPTAL DEFECTS

To date, various methods have been suggested, or have been attempted, for closure of interauricular septal openings; they fall

Fig. 16. Method of placing sutures in the edge of a septal defect, working through an atrial well. 1, Atraumatic needle carrying No. 000 Deknatel silk. Position of needle in needleholder. 2, Left index finger exploring the septal defect and identifying its margin. 3, With the right hand, a 10 inch long, diamond-jawed needle holder carries the needle into place, grasping 3 or 4 millimeters of the septal edge. 4, The needle holder is given to an assistant who keeps upward traction on it. The presenting point of the needle is palpated with left index finger and grasped with a right angle clamp. 5, Original needle holder removed, right angle clamp still grasping the needle. 6, Needle recovered. When a septal closure is to be made by direct suture, the 30 inch threads should carry an atraumatic needle at either end to facilitate placement of suture through both sides of the septal margins.

into four general categories: (1) external transfixion of the auricles with mattress sutures placed in the plane of the septum; (2) invagination of atrial appendages, or lateral wall of an auricle, to plug the defect; (3) introduction of plastic material to cover the orifice; (4) closure of the opening under direct vision while the septum is isolated from the circulation by a special clamp or while blood is diverted from the opened heart.

1. Murray has passed large mattress sutures of silk through the heart, placing these approximately in the plane of the atrial septum. Snugging up of these sutures compresses the heart anteroposteriorly, and in some cases partially diminishes the size of the atrial opening. Certainly, the method gives no promise of closing a septal defect completely. Although clinical improvement has been reported in several patients subjected to this procedure, no decisive evidence has been presented yet to show that the shunts have actually been reduced.

2. Various workers have devised methods for invaginating the atrial appendages or the lateral wall of an auricle to occlude a septal opening. Swan and his co-workers have inverted both the right and left auricular appendages to the septum, occluding the defect by holding the inverted appendages in this position with mattress sutures which pass through both of the appendage tips. The use of this procedure in humans has been abandoned by Swan, because of the danger of partially obstructing orifices of the pulmonary veins. Santy and his associates reported the plugging of a small septal opening by inverting the tip of an auricular appendage through it. Cohn has suggested inversion of the right auricular wall toward the septum, anchoring it in this position by sewing it to the septum with sutures which have been introduced from the exterior of the heart. Bailey has modified this by introducing a finger through the auricular appendage, so that the digit inside of the auricular cavity could guide the placement of the sutures around the edges of the septal defect. While these various techniques of inversion of an auricular wall (or appendage) to the septum might be highly satisfactory for closure of centrally placed defects, it is well to remember that many of the septal openings in humans are located very high, very low, or very far forward, so that the inversion of an appendage (or auricular wall) to occlude them would almost certainly give partial obstruction of the superior vena cava, the inferior vena cava, the coronary sinus, the tricuspid valve, or the pulmonary veins.

3. Experimentally produced atrial defects have been closed successfully with appliances made of plastic materials. Hufnagel and Gillespie have accomplished this in animals through an incision in the atrial appendage (controlled by a pursestring suture), introducing a two piece button which is manipulated into such a position that it occludes the defect. One disc is placed on the left of the septum and the other on the right side; then the two can be screwed to each other by a simple and ingenious handle, the discs being anchored into place by grasping edges of septum around the periphery of the septal opening. The secure placement of such buttons requires a rim of septal tissue around a considerable portion of the circumference of the defect—a condition which is all too frequently absent in the naturally occurring malformations.

Martin and Essex have described the introduction of sheets of plastic material into the heart of dogs through an incision made in the atrial wall. Sutures are attached to this prosthesis. The plate is secured in place by passing the threads from within the atrium to the external surface of the heart approximately in the plane of the septum. It is obvious that the edge of a defect near the annulus of the tricuspid valve could not be firmly closed by this method. No accurate method is suggested for placement of the sutures, or for positioning the prosthesis. We are convinced that it is impossible to accomplish either of these manipulations in a reasonably satisfactory way by palpation through a thickened lateral wall of an auricle.

4. In attempts to close septal defects in dogs under direct vision Swan and his coworkers and Martin and Essex have temporarily occluded the caval inflow and have opened the heart for short periods of time while the circulation was thus interrupted.

This drastic maneuver, while tolerated temporarily, cannot be continued for more than a few minutes; it would certainly seem to be impractical for the closure of large defects. Furthermore, it is quite doubtful (in the presence of septal openings) whether it would be possible to prevent embolization of air into the systemic arteries.

A simple method for the repair of septal defects under direct vision has been suggested by Dodrill, who constructed a special ring-shaped clamp for temporary compression of the lateral walls of both atria against the septum. Although it is possible to incise the auricular wall within the ring of this clamp and have a bloodless field, the operative area is small and is entirely limited to the central portion of the septum; the method will probably have little use for closure of septal defects in man. Furthermore, serious arrhythmias and heart failure were observed during the temporary applications of such a clamp.

Considerable information has been accumulated regarding the technical designs and capabilities of various mechanical pump-oxygenators which could divert blood from the heart while the organ is temporarily open. Little information is yet available concerning the use of these appliances during actual intracardiac operations on humans. Dennis and his associates have reported experiences in the use of a mechanical heart-lung machine attached to a human, with an attempt at suture of an atrial defect under direct vision after opening the heart. To date, no successful repair has been reported by this method. While enormous strides have been made in the perfection of machines for temporary diversion of blood from the heart, there is yet much to be learned concerning the various problems dependent upon the use of these during intracardiac operations in humans.

Summary. The various methods listed which have been suggested or have been tried for the obliteration of auricular septal openings in man have focused attention of surgeons on the problems at hand. Obviously, some of the techniques will not be of practical value. Others will be found to be very satisfactory for treatment of certain kinds of openings but ineffective or hazardous for others. It is evident that a more versatile method must be developed if we are to be able to treat all variations of septal anomalies which are known to occur in humans.

Fig. 1. Type of small, rubber atrial well attached to the right auricle of a dog. From the opened auricle, blood rises up into the rubber well.

LABORATORY STUDIES IN THE DEVELOPMENT AND PERFECTION OF AN ATRIAL WELL

As a new approach to the problem of surgically closing interauricular septal apertures, it seemed to us that it might be possible to attach temporarily to the heart some sort of a hollow cylinder, into the base of which the auricle could be opened. Blood would rise up into the receptacle for a distance equal to the intra-auricular pressure, which should not be more than a few centimeters. If it were possible to couple such an appliance to the heart, it might then be feasible to work through this pool of blood in a blind manner, but deliberately with the guidance of exploring fingers, so that a septal opening could be approached and could be occluded by some appropriate means. Our initial experiences involved considerable trial and error evaluation of various ways of securing a rubber cylinder or "well" to the side of the auricle, locating a well in the

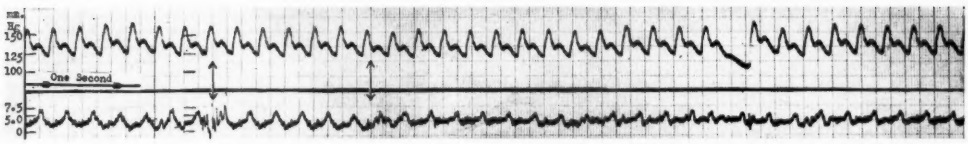

Fig. 2. Continuous pressure recording during the opening of the right atrium of a dog. Top tracing is carotid arterial pressure; lower tracing is effective right atrial pressure. A rubber well has already been sutured to the side of the right atrium. At the first arrow, the atrial clamp was released; by the time of the second arrow, the atrial well was widely open. Note the absence of any important influence on carotid arterial pressure or atrial pressure.

best possible location for giving the optimum access to the atrial septum, and of studying methods for prevention of coagulation of blood in the appliance.

To attach a piece of rubber to the surface of the heart in a leakproof manner, it was hoped that a union could be made with rubber cement or other adhesive material, but all of these were found to be ineffectual. Without enumerating the various methods which we found to be unreliable, it was eventually discovered that it was possible to join a hollow rubber bag to an auricle with a number of interrupted stitches of No. 0000 Deknatel silk, as indicated in Figure 1. The coupling together of the two structures required no more than 10 to 15 minutes; the junction could be made watertight.

Numerous designs for a rubber well were tried before evolving the one which seemed to be most suitable for the purposes we had in mind. For work on dogs, a satisfactory form is shown in Figure 1. It is made of latex rubber, is 0.38 millimeter thick, is 10 centimeters high, has an upper orifice 10 centimeters in diameter, this opening being held expanded by a circular stainless steel spring incorporated into the rubber. The lower orifice is 3 centimeters in diameter and its rim has been reinforced to a thickness of 1 millimeter to withstand the piercing of sutures and the stretching to which it is subjected.

Two special instruments were required. One was a clamp, to pinch off and isolate a small segment of the atrium while the well was being attached. The second was a self-retaining retractor for insertion into the slit in the atrial wall (at the base of the well) so that the auricular opening could be spread to an adequate diameter for allowing fingers to pass into the auricle.

Early in the studies, it became evident that it was easier to approach the septum through the right atrium than through the left one, because a larger surface of atrial wall was available, a better angle of approach was afforded, the septum lay higher in the surgical field, and finally, the venae cavae would be available if at any time it seemed desirable to occlude them temporarily.

Exposure of the heart and attachment of a well. One hundred and fourteen adult mongrel dogs, ranging in weight from 17 to 26 kilograms, were employed to develop a method of attachment of an atrial well and also to become proficient in the performance of the

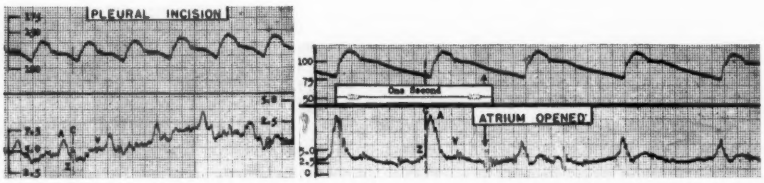

Fig. 3. Observations on circulatory dynamics at opening of pleura and at opening of an atrium. Top tracing is of carotid arterial pressure; lower tracing is effective right atrial pressure. At the time of opening of the right pleura, the interatrial pressure at first rises (as suction effect of negative intrathoracic pressure is lost). The carotid arterial pressure shows a slight rise. At the time of opening the atrium there is a fall in the effective atrial pressure and there is no change in the carotid arterial pressure.

Fig. 4. Carotid arterial pressure (above) and effective right atrial pressure (below) during various phases of an atrial well operation on a dog. 1, Preoperative tracing, following nembutal anesthesia. 2, After incision of chest wall, but before opening of pleura. 3, Thirty minutes after opening of right pleural sac. The atrial pressure has risen. 4, Thirty seconds after opening right atrium into a rubber well. The effective atrial pressure and the carotid arterial pressure have fallen slightly. 5, After creation of an interatrial septal defect and then closure of it by the suture onlay of a plastic disc. By now the well had been open 45 minutes. There has been some fall in arterial pressure, but it is still at an adequate level. 6, After completion of operation. The atrial well has been removed, the pericardium closed, the lung expanded, and the chest closed. Following this restoration of subatmospheric intrathoracic pressure, the effective atrial pressure has been raised and the arterial pressure has become stabilized at a higher level.

maneuvers. Anesthesia was induced with intravenous nembutal. Atropine was given to minimize any deleterious reflex reactions. Lung aeration was provided by a mechanical insufflator during the thoracotomy. Oxygen was given after the cardiac manipulations were started. In the latter part of the series, all animals received transfusions of unmatched whole dog blood in amounts which were sufficient to replace that which had been lost from the circulation.

The right pleural space was entered through the fifth or sixth intercostal muscles. Ten cubic centimeters of 2 per cent solution of procaine hydrochloride were injected into the pericardial sac, which was then entered parallel and anterior to the phrenic nerve. The lung was packed away by gauze pads. The posterior flap of opened pericardium was pulled upward with traction sutures, a maneuver which helped to raise the heart in the operative field and make it more accessible.

The best exposure of all parts of the septum was obtained by the placement of a well very low on the right atrial wall. A segment of the auricle was isolated by the application of an atrial clamp. The isolated portion was then incised and the well was secured around its periphery with interrupted stitches. The strands of silk were left long to facilitate traction and manipulation of them during the opening of the well. The inner surface of the well was moistened with heparin solution and the atrial clamp released so that the blood could flow up into it. At this point, traction on the anterior and posterior silk sutures at the base of the well pulled open the auricular orifice and this facilitated insertion of the self-retaining retractor into it. Both the retractor and the rubber well could then be supported by one hand of an assistant.

In the earlier experiments, animals were completely heparinized to prevent clotting of blood in the open well. There was a prohibitive mortality from postoperative hemothorax, despite careful hemostasis and the administra-

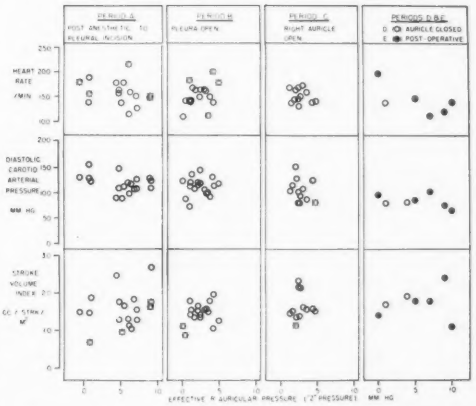

Fig. 5. Observations on heart rate, carotid diastolic arterial pressure, and the stroke volume index during various periods of atrial well operations on dogs. Fifty-five observations from 8 animals have been plotted. Period A, Following induction by nembutal anesthesia. Period B, Following opening of pleural sac to atmospheric pressure. Period C, Following opening of the right auricle into a rubber well. Period D, Following closure of the auricle and, Period E, following closure of the chest. The significant finding is the absence of any important deviation from the general levels of the pulse rate, arterial pressure, and stroke volume during period C when the well is open.

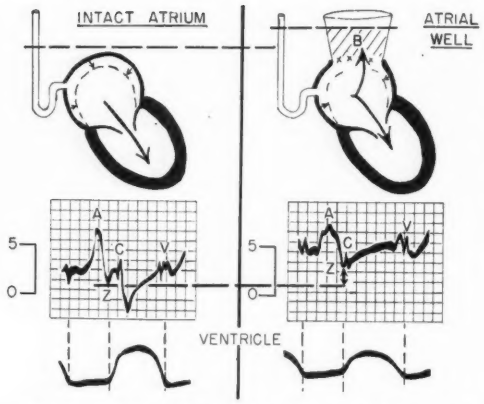

Fig. 6. Influence of an atrial well on the dynamics of ventricular filling. Left, With the intact atrium, the atrial pressure is at a low level but the contraction of atrial systole is effective in propelling blood into the relaxed ventricle. Right, With an atrial well in place, the atrial pulse wave is damped, because masses of blood fluctuate in and out of the well during each atrial contraction. An elevation of end-diastolic atrial pressure (*Z*) compensates for the loss of effectual atrial contraction. At the bottom, a schematic ventricular pulse is shown for purposes of orientation to the components of the atrial pressure pulse.

tion of adequate amounts of protamine sulfate after operation. It was soon found that blood could be prevented from clotting in a well by merely adding to it every few minutes a few cubic centimeters of 0.01 per cent heparin solution in 0.9 per cent sodium chloride. No animal received more than 20 milligrams of heparin. Following operation, it was not necessary to inactivate any small amount of heparin which had entered the general circulation. Pulmonary embolization was not observed in any instance.

Intracardiac manipulations. With the well open it was possible to introduce exploring fingers into an auricular cavity and to identify easily and accurately the caval orifices, the tricuspid valve, the coronary sinus, and the entire septum including the fossa ovalis and the limbus. The eustachian valve was difficult to identify in those animals where it was thin or rudimentary.

Removal of atrial well; closure of atrium. After intracardiac exploration or manipulations had been carried out, the well could be very simply removed by withdrawing the self-retaining retractor, replacement of a clamp across the auricle to shut off the base of the well from the general auricular cavity, and then cutting the various silk sutures which had anchored the rubber appliance to the heart. There was no difficulty in repairing the auricle with interrupted figure-of-eight stitches of No. 0000 Deknatel silk. After lavage of any blood from the pericardial sac, the latter could be closed loosely.

PHYSIOLOGIC STUDIES OF CARDIOVASCULAR SYSTEM WHILE AURICLE WAS OPENED INTO AN ATRIAL WELL

Operative manipulations on the wall of an auricle frequently set up extrasystoles. Serious disorders of rhythm were extremely rare after completion of the attachment and during the time when the appliance was being left open. Studies on the cardiovascular dynamics were conducted on a small group of animals. Pressures were measured[1] in the carotid artery, the right atrium, and the right pleural space (Figs. 2, 3, 4, and 5). From these data, various calculations could be made. It was found that: (a) After opening the well, the wave of atrial systole (designated *A* on the tracings) is damped but is not abolished. (b) The other components of the atrial pulse are also damped. (c) There is a rise of mean atrial pressure and end-diastolic pressure after the well has been open for several minutes. The end-diastolic pressure (designated *Z*) is the pressure in the atrium at the end of ventricular diastole and is an important determinant of the volume of ventricular filling. The observed elevation of end-diastolic pressure is thought to be a compensatory mechanism whereby the animal maintains ventricular

[1]The pressure measurements were made with capacitance manometers and a two-channel direct-writing oscillograph. The hydraulic and recording systems demonstrated a satisfactory frequency response during square wave impact experiments. Atrial and pleural pressure pulses were calibrated frequently with a saline manometer graduated directly in equivalent mercury pressures and corrected to a zero point at the uppermost wall of the right atrium as measured at each operation. The value, *effective atrial pressure*, was calculated as the difference between the pressure within the atrium and the pressure outside the atrium in the closed heart, e.g. the pleural pressure, thereby correcting for variations in subatmospheric intrathoracic pressure. The pleural pressure was assumed to equal atmospheric pressure when the chest was open. All atrial pressure observations reported are typical values recorded late in expiration or late between insufflator blasts. Stroke volume indices were calculated by the modified Hamilton-Remington arterial pulse contour method (9) using enlarged camera obscura tracings of the carotid pulse.

filling in the absence of competent atrial pulsation. (d) Following the time that blood had been allowed to escape up into a well, there was a tendency for the peripheral arterial pressure to fall slightly. Undoubtedly, this was due to the loss of blood from the circulation by the segregation of it into the atrial well but in addition there must have been the influence of those factors which prevail during any long and complicated thoracotomy. The peripheral arterial pressure could be kept at a satisfactory level by the intravenous transfusion of blood shortly after a well had been opened.

We could find no precise relationship between preoperative atrial pressure and the height to which blood would rise in the open well at operation. When effective atrial pressure was low after induction of nembutal anesthesia, no fall of pressure occurred when the pleural sac was opened, but when effective atrial pressure was maintained after barbiturate administration, an appreciable drop of atrial pressure occurred as the chest was opened. This phenomenon resulted in wide variations of preoperative effective atrial pressure falling into a narrow low range by the time the well was to be opened. Consequently, fluid levels in the well were never disturbingly high.

There was no evidence of cardiac decompensation in the dogs as a result of well operations. In Figures 4 and 5 it can be seen that during successive periods of the operation, the response of the myocardium does not alter, since arterial pressure and stroke volume values late in the operative procedures are comparable to those during early periods of the operation. This was observed in spite of the fact that the well was kept open for periods up to 1 hour. It is likely that in these animals the wells could have been left open for much longer intervals without deleterious effects.

CREATION OF INTERAURICULAR DEFECTS

By working through atrial wells, interauricular septal openings were created. After a small opening was made in the center of the fossa ovalis by puncture with a hemostat, the edges around this wound could be grasped with a curved hemostat, elevated, and the defect enlarged by peripheral excision of tissue. The excised substance was always held in the hemostat so that tissue embolization did not occur. Defects could be made, varying in size up to 2.5 centimeters in diameter. Creation of an opening was followed by the appearance of arterialized bright red blood in the well, without an appreciable change in the level of blood within the well.

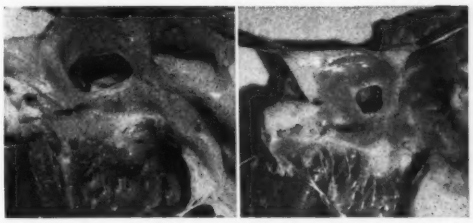

Fig. 7. Interauricular defects made in dogs, working through an atrial well and cutting out portions of the septum. Left, Defect 22 days after operation, the opening measures 2.0 centimeters in maximum dimensions. Right, Auricular septal defect 3 months after its establishment. The opening measures 1.5 centimeters in diameter. Probe lies in the coronary sinus.

Recent publications have emphasized the difficulty of making septal orifices in laboratory animals which will remain open permanently. There is rather general agreement that artificially made holes of small size can close spontaneously and rather promptly. However, we believe that this is not entirely true when openings of great size are made. While it is evident that there is some cicatrization in the surrounding septum and a definite diminution in the size of the septal opening large windows will remain for considerable periods of time (Fig. 7).

STUDY OF METHODS FOR CLOSURE OF INTERAURICULAR SEPTAL DEFECTS

By carrying out manipulations through atrial wells, attempts were made to close artificially made atrial defects in 68 dogs. Four general methods for obliteration were studied: (1) by sewing over the defect pieces of animal tissue, such as an excised atrial appendage, a plaque of pericardium, or a segment of vein; (2) by the application of Hufnagel double disc plastic buttons; (3) by the onlay of a sheet of plastic material which

Fig. 8. Experimental closure of artificially made interauricular septal defect by sewing a piece of free auricular appendage over the opening. Left, Appearance in right auricle 14 days after operation. There is complete closure of the defect by the graft. Right, View in the left atrium.

was sutured to the surrounding septum; (4) by direct stitching and approximation of the septal edges.

1. *Atrial appendage graft.* A resected portion of atrial appendage presents many desirable characteristics when used as an intracardiac graft. It is organic tissue and it is easily available in the operative field. Its bulk makes for ease of handling. In 22 animals auricular appendage grafts were used to close septal defects. Eleven of these were autologous. For the other 11 experiments, atrial appendages were removed from donor dogs under aseptic conditions, sealed in sterile plastic envelopes, and stored in carbon dioxide ice deep-freeze at −76 degrees C. for periods between 3 and 14 weeks. In each experiment a piece of appendage of appropriate size was sutured to the interauricular septum in such a manner as to close over and plug the existing artificially made defect.

Surface thrombus formation on these grafts rarely exceeded a millimeter or two in thickness and was usually most prominent in the declivities between the trabeculae carneae of the graft and at the junctions between graft and septum. In successive weeks, keeping pace with organization of the graft, there was gradual contraction of the graft to approximately one third of its original size. Within a few weeks the graft became covered with a smooth coat of endothelium, presenting an irregular but smooth interior to the auricle (Fig. 8). When examined beyond 3 months, the identity of the graft was completely lost and the region was represented by a small contracted scar, with smooth surfaces.

Fig. 9. Experimental closure of artificially made interauricular septal defect by application of Hufnagel double disc buttons. Left, Showing button in place, covering the septal opening. Dog sacrificed at end of operation. Right, Heart from an animal sacrificed 12 weeks after insertion of buttons. The button is completely incorporated within the substance of the septum and is entirely covered by endothelium.

Histologic examination of such grafts at different times after their placement showed certain changes. In about a week the muscle fibers were becoming pale, homogeneous, and eosinophilic; there was disappearance of the nuclei and loss of muscle striations. These findings persisted and progressed for several weeks until the muscle was replaced by connective tissue. At no time was there any tendency to fragmentation or disintegration of the graft substance. Instead, its unity was maintained, in spite of progressive loss of its histologic elements, and the entire structure gradually became completely replaced with fibrous tissue and formed an integral part of the septum. Endothelization was usually complete in 10 to 14 days. Beyond 3 months there was a decrease in local vascularity, a condensation of the connective tissue, and a greater deposition of collagenous substance. In scattered areas the deposition was extremely dense and consisted of whorls of deeply basophilic material. In some grafts, small deposits of calcium were seen.

There was little difference in the overall results from the autologous and the homologous appendage grafts, excepting that in the latter the process of healing was slower by several weeks; the same end result being eventually achieved.

Vein or pericardial graft. Segments of external jugular vein (turned inside out) or sections of pericardium were utilized as free grafts for closure of septal defects in 4 dogs; they were sewed into place. Thrombus formation was negligible. Most of these tissues underwent progressive histologic regression, were replaced by scar tissue which became a

part of the septum, and became smooth covered by endothelium. However, there were important disadvantages in the use of either of these materials. First, veins of sufficient size were not obtainable for closure of very large defects. Second, pericardium was troublesome to work with because it was so thin and limpid that it was difficult to place a number of stitches around its periphery and through the septal wall without producing a hopelessly twisted mass of strings before all of these sutures could be tied when the graft was pushed down into the depths of the auricle.

2. *Plastic buttons.* Paired plastic buttons, fashioned after those described by Hufnagel and Gillespie were machined from lucite or kel-F and were used for occlusion of septal openings in 6 dogs. The plastic buttons were put into place with the handle devised by Hufnagel. One disc of the button was placed on the left side of the septum and its mate introduced on the right. The buttons were then screwed together, being held firmly apposed to each other by virtue of the central threaded stem and core which they possess (Fig. 9). Within a few minutes such plastic buttons were covered with a layer of fibrin or a sheet of thrombus less than a millimeter in thickness. This overlying fibrinous clot rapidly became organized and then covered by a continuous layer of endothelium within 2 or 3 weeks. The buttons were tolerated extremely well and became incorporated into the septum in an amazing way.

The greatest value of buttons is derived from the speed with which they can be inserted. All of the intracardiac manipulations could be completed within a few minutes. For their use, it was essential to have a complete margin of tissue around the septal opening for the prosthesis to grasp and hold on to.

3. *Onlay of plastics, sewed into place.* In 30 dogs, septal defects were closed by the onlay of discs or sheets of plastic materials which were sewed to the surrounding septum with silk sutures. Materials studied were nylon (0.13 mm. and 0.81 mm. thick), polyethylene (0.51 mm. and 1.52 mm. thick), and lucite (3.17 mm. thick). The meagerness of tissue reaction to these substances, when pure, has been described (6).

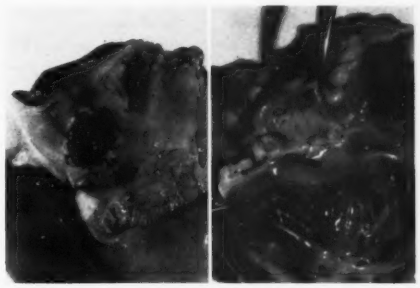

Fig. 10. Experimental closure of interauricular septal defect by the onlay of a sheet of nylon sutured into place with silk sutures around its periphery. Left, Photograph of plastic sheet sewed into place, animal sacrificed at the end of operation. Right, Animal sacrificed 16 weeks after closure of a septal defect by a sheet of nylon, 0.8 millimeter thick. The foreign material is well tolerated by the septum and is completely covered by fibrous tissue and endothelium.

Both nylon and polyethylene film are sufficiently soft and pliable to be cut readily by scissors and shaped to desired size at the operating table, yet stiff enough to be easily manageable. The alignment of numerous sutures around their periphery can be maintained. These materials are easily pierced with needles. Sutures are not cut by the edge of the plastic. Because of their extreme hardness, discs of lucite must be prepared before operation; they have to be machined to appropriate sizes; holes must be drilled around the edges of the plates to receive sutures.

After these various plastics were sewed onto septums, the rapidity with which they were covered was striking. The observed changes were closely similar for each of the substances.

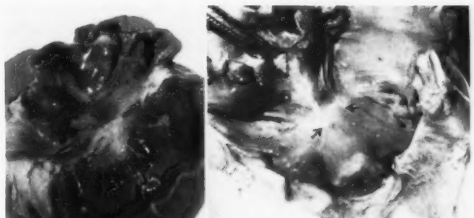

Fig. 11. Experimental closure of interauricular septal defects in dogs by direct suture of a septal opening. Left, Opening closed with interrupted silk stitches, animal sacrificed at end of operation. Right, Specimen from dog sacrificed 5 weeks after closure of interauricular septal defect by direct suture. Between the arrows is an irregular scarred area indicating the operative site. Silk sutures are completely incorporated within the substance of the septum.

Within a few hours after operation there was a fine layer of thrombus, less than a millimeter thick, on both sides of the foreign material. This thrombus was loosely adherent to the plastic but was tightly enmeshed in the sutures and the suture knots. Several dogs sacrificed 1 week after operation showed a slight increase in the thickness of the thrombus, usually not greater than 2 millimeters. By then the clot was generally compact, glistening, and smooth. After 2 weeks there was a rapid conversion of the thin purple-red thrombus to a fibrous covering, this change starting at the periphery and progressing toward the center. Endothelization was always complete in 2 or 3 weeks. Beyond 6 to 12 weeks plastics were encased in a tough, white fibrous membrane, which blended imperceptibly with the adjacent septal tissue. The plastic materials always became sequestrated within the septum; in no instance was there any formation of cyst around them.

The only disturbing reaction to plastics was the tendency for more pronounced thrombus formation on the plates of 0.81 millimeter nylon. These were solitary, sessile, rounded masses of clot as large as a centimeter in diameter. In a few months these became contracted, hard nubbins of scar tissue 2 to 4 millimeters in diameter, well covered by endothelium and firmly adherent to underlying structures. Embolization from these lesions was never demonstrated. Such a reaction might have been due to the presence of foreign substances (plasticizers) in the lot of nylon which was employed.

Our conclusions regarding these plastic materials (sewed into place) were as follows: All of the substances are tolerated very well and become covered over in an amazing way. *Lucite* is not practical because its great hardness requires that it be machined and also drilled beforehand. Furthermore, it is too rigid and will not adapt itself to those septa which do not have a flat contour. *Nylon* sheet is very satisfactory, can be cut with scissors at the operating table, and can be easily pierced with needles. The sheets 0.081 millimeter thick caused some reactions which, while apparently not harmful, might be best to avoid. Thinner sheets did not produce the reaction and were very satisfactory. *Polyethylene* sheeting was highly satisfactory; the 1.52 millimeter thickness was unnecessarily heavy, while the 0.51 millimeter thickness had all the desirable characteristics. It could be cut easily, could be pierced with needles, had enough substance so that it did not flop or fold over, but yet would bend sufficiently to adapt itself to any irregularity of septal contour to which it was applied. It had sufficient body and stiffness so that it could easily be palpated and guided into place with fingers in the auricle. This material appeared to be overwhelmingly the one of choice for onlay closure of septal defects.

4. *Suture closure.* In 6 dogs, septal defects were closed by direct approximation of the septal borders with interrupted silk sutures. The animals were sacrified at varying times up to 6 months. For the first few days there was a regional, fine layer of thin thrombus overlying the operative site. This gradually became organized and merged with the substance of the septum. The sutures always became buried in this cicatrix. Within 3 or 4 weeks the region was endothelialized and was represented solely by irregular, contracted scar, which was smoothly covered.

To suture septal defects, working through an atrial well might seem to present formidable problems of technique. We were surprised to find that with a little practice it was possible to carry out the manipulations of placement and tying of stitches in the depths of a pool of blood. It was not necessary to design special instruments for holding needles. A good holder is 10½ inches long and had diamond jaws which prevent a needle from turning. The needle is grasped as shown in Figure 16, 1. With the left index finger the margin of the septal defect can be palpated; with the needle holder in the right hand, the needle can be made to grasp and pierce the septal tissue, 3 or 4 millimeters back from its edge. The needle holder is then transferred to an assistant who carefully maintains the impalement of the needle by upward traction. The point of the needle can then be grasped with a right angle clamp, following which the original needle holder is released and removed. The right angle clamp can then draw the

needle out of the wound. It is highly important to use only atraumatic needles since this insures that (if lost) they can be instantaneously retrieved by pulling up on the silk thread which emerges from the well.

There is no clear-cut separation of defects into those which can or cannot be closed by direct stitching. In general, smaller openings (less than a centimeter in width) which have thick and firm substance in the adjacent septum can be sutured with a reasonable expectancy of obtaining a complete and permanent closure. Conversely, defects which are larger than 1 or 1.5 centimeters in width, which have only thin substance surrounding them, or which have incomplete rims of tissue, should not be sutured because too much tension will be placed on the stitches, some of the threads will tear out, and incomplete closures will result.

Summary. Attempts at obliteration of artificially made septal defects were carried out in 68 dogs, working through right atrial wells. The animals were sacrificed at varying periods of time up to 6 months after operation. Complete closures were observed in 60 animals at autopsy; in 8 dogs there were small residual holes ranging up to 4 millimeters in diameter. These incomplete closures almost certainly resulted from tearing out of stitches or the poor placement of sutures. Without doubt, success in the obliteration of septal defects is closely related to the extent of the operator's experience and his manual dexterity when working with a heart; in the last 30 of our attempts to repair septal apertures, the opening was found to be completely occluded at subsequent autopsy examination.

SURGICAL CLOSURE OF SEPTAL DEFECTS IN HUMANS

After laboratory experimentation with the atrial well approach to the interior of an auricle, it was felt justifiable to attempt closure of interauricular septal openings in humans. To date, 7 subjects have been operated upon. We are greatly indebted to Dr. Alexander S. Nadas and Dr. Walter Goodale for aid in study and care of these patients.

Believing that the atrial pressures to be encountered in man with cardiac anomalies might be higher than those which had been found in normal dogs, a new and larger rubber well was designed to care for this contingency. A well was constructed which had a height of 15 centimeters, an upper orifice 13 centimeters in diameter, a lower orifice 5 centimeters in diameter, and a rather capacious contour which would admit an entire hand (Fig. 12). To accompany this, an atrial clamp was de-

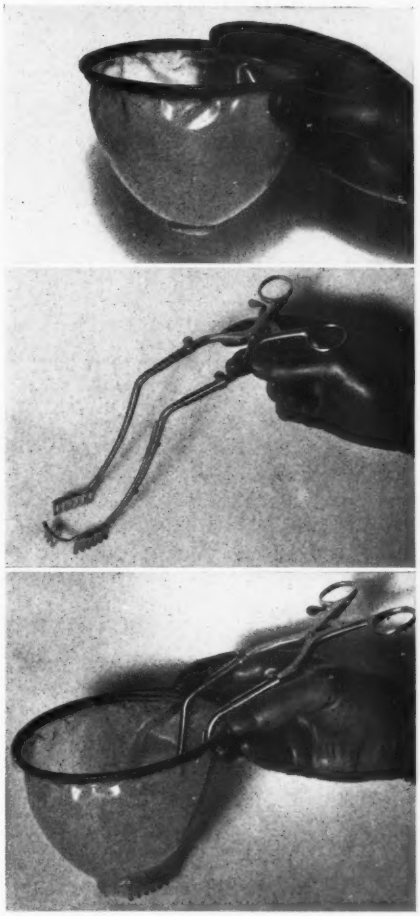

Fig. 12. Atrial well of large size, constructed for application to human hearts. Above, Photograph of the rubber well. Middle, Self-retaining retractor for insertion into the well and spreading of its neck. Below, Showing method of placement of retractor into the well so that its neck can be appropriately spread. An assistant can support both the retractor and the well as shown.

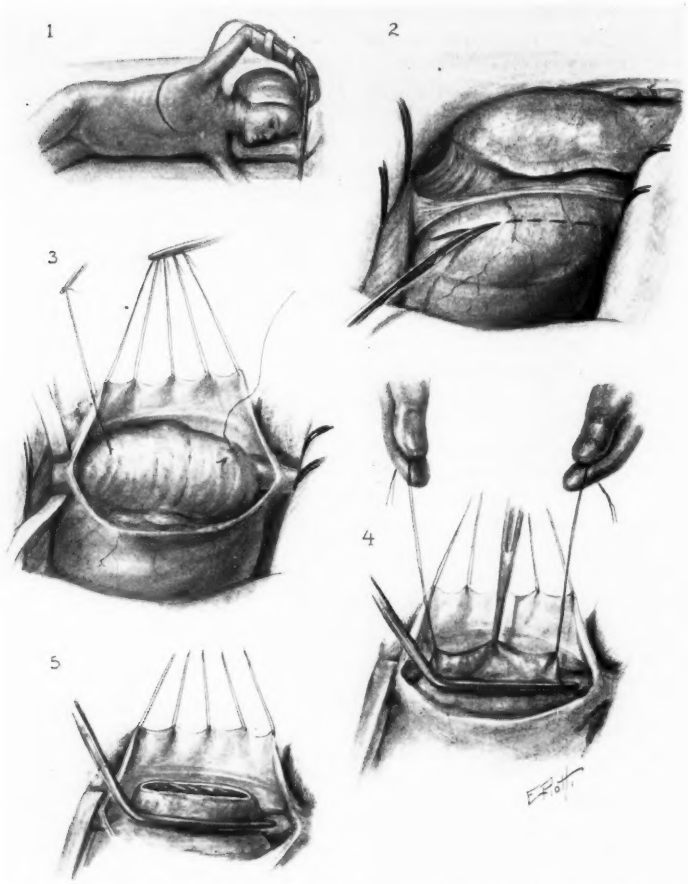

Fig. 13. Method of application of well to the human heart. 1, Position of patient on table. Surgical approach through the fifth interspace. 2, Lung falls toward the patient's back, pericardium being opened along the dotted line. 3, Flap of pericardium held upward and backward. Traction on this helps to raise heart into the operative field. Two traction sutures being applied to the greatly enlarged right atrium. 4, Segment of right atrium being held up while an atrial clamp is put into place to isolate this segment from the auricular cavity. 5, The isolated segment of atrium cut open.

vised, the jaws of which were 6 centimeters in length and which were prominently knurled so that they would not slip. Next, a self-retaining retractor of greater depth and with larger jaws was manufactured. When subsequently used on human patients, these devices were all found to be completely satisfactory.

At first, we were somewhat concerned about the height of columns of blood which would be encountered in human atrial wells, feeling that there might be little correlation with pressures which had been observed at preoperative catheterization. In the 7 patients, the right atrial pressures before operation were 4, 8, 14, 8, 14, 15, and 7 centimeters of saline respectively. Generally, heights of blood columns in the wells at operation were much lower than these figures.

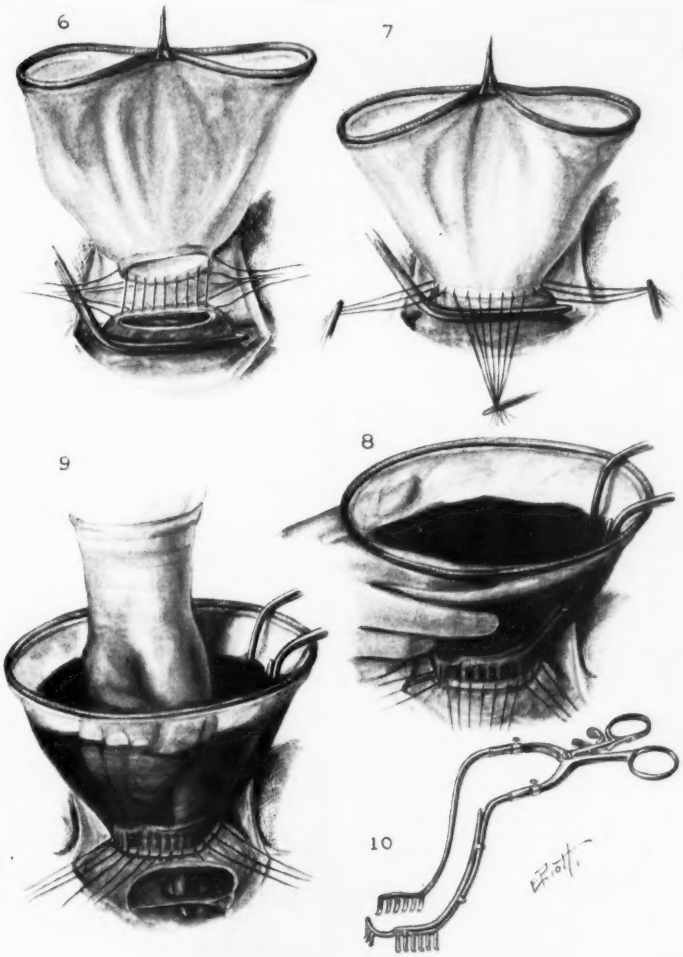

Fig. 14. Continuation of human atrial well operation. 6, Rubber well being brought into place and attached to atrial wall with interrupted silk sutures around the periphery of its lower rim. 7, Attachment of well to atrium completed. 8, Atrial clamp removed, allowing blood to flow up into the well. 9, Exploring hand run down through the pool of blood so that a finger can feel the interauricular septal defect and estimate the size and position of the septal opening as well as the nature of its edges. 10, Type of self-retaining retractor which holds open the atrial wall. An orifice 5 or 6 centimeters in diameter is sufficient to permit unhindered intracardiac manipulations.

Operation in each instance was under general anesthesia with ether by use of a tracheal tube and a closed system. Exposure was made throughout the entire length of the right fifth interspace, the sixth and seventh ribs being divided posteriorly and the fifth, fourth, and third cartilages cut near their sternal junctions. A wide opening of the chest wall was found to be essential. Techniques of applying and using a right atrial well are illustrated in

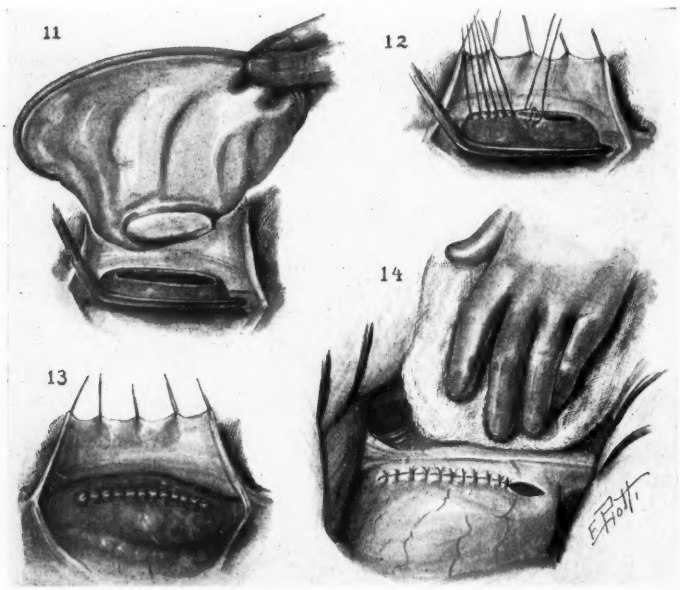

Fig. 15. Human atrial well operation, continued. Method of removal of the well at completion of operation. 11, The atrial clamp reapplied, after which the rubber well is cut away from the heart. 12, Closure of the atrial wall with interrupted figure-of-eight silk sutures. 13, Closure of auricle completed. Atrial clamp removed. 14, Closure of pericardial sac.

Figures 13, 14, and 15. In every case there was a greatly enlarged right auricle (as determined by roentgenographic study before operation and as confirmed at the operating table) so that there was plenty of auricular surface for attachment of the rubber appliance to the heart wall.

Because of the large flow of blood through the pulmonary circuit, the presenting right lung was always found to be heavy with blood, always had a distinct thrill in its central vessels, and had enormously distended and tense pulmonary veins where they could be seen behind the heart.

In 5 of the patients, 8 to 10 cubic centimeters of 2 per cent procaine were injected into the pericardial sac before opening it; in the other 2 this substance was not used. We are inclined to think that such use of procaine is not of real value in reducing the irritability of the heart. In some instances it seemed to depress the cardiac activity and to produce a mild fall in the peripheral arterial pressure. We now prefer to omit the use of procaine as a routine measure and to bathe it onto the surface of only those hearts which seem to be irritable as an atrial well is being attached to it. In only 1 case was pronestyl employed.

After the pericardium was opened, it was dissected away from the terminal portion of the inferior vena cava, to make certain that this region was freed so that the atrial well could be placed as far inferiorly and posteriorly on the auricular wall as possible, thus to facilitate and give the best possible positioning for the transauricular approach to the septum.

Linen tapes were always passed around the inferior and the superior vena cava so that if a defect should be found very low or very high in the septum and near the orifice of either vena cava, the cava could be pulled forward and the plastic plate which was to be used for occlusion of the septal defect could be run up against and attached to the auricular wall just *medial* to the orifice of the cava. This

would make sure that all caval blood would be diverted into the right atrium. The lower cava could be encircled with a tape either inside or outside of the pericardium. For the superior vena cava, it was found that encirclement of the structure within the pericardium gave irritation of the nearby sino-auricular node and produced disturbing extrasystoles. Therefore, it was best to run the tape around the superior vena cava just above the pericardium.

There was no difficulty in any instance attaching a rubber well to the auricular wall. This could be made completely leakproof. It took from 15 to 20 minutes to sew the appliance in place.

Before allowing blood to run up into a well, its interior was flushed with 0.04 per cent heparin in 0.9 per cent sodium chloride. After blood entered the well, a few cubic centimeters of this material were added by an assistant every few minutes. In no instance was there clotting. From time to time the operator's gloves were rinsed with heparin solution.

The wells were all tolerated in an extraordinary manner. In some cases there were a few extrasystoles during attachment of the rubber bag and the handling of the atrial well. These were never troublesome. The wells were left open for times varying from 12 minutes up to 2 hours and 5 minutes! There seemed to be no doubt that cardiovascular adjustments to the appliance could be made without difficulty, even in patients who previously had been in failure, and that there need be no haste during the intracardiac manipulations. It was possible to make deliberate and careful examination of the interior of an auricle and to carry out the various steps for closure of the defects which were found.

Regarding the use of transfusions during operation, three general rules were employed: (1) Immediately after opening the auricle into a rubber well, blood was given intravenously to compensate for that which had been "lost" into the rubber sac. This varied from 1 to about 300 cubic centimeters in amount. (2) From here on throughout that portion of the operation while the well was open, relatively small volumes of blood were infused, using only amounts which would be reasonable for an intrathoracic procedure of the given duration, throughout which very little blood was being lost. (3) After closure of the atrium, the blood which remained in the well (usually several hundred centimeters) was discarded and the patient was *not* transfused with a similar amount. By using these general guides, but altering them somewhat in relation to the patient's pulse rate and peripheral arterial pressure, there was no difficulty in any case in keeping the patient in a very satisfactory state during the operative procedure.

After removal of an atrial well, there was no problem in attaining a tight closure of the lateral wall of the auricle, this being accomplished with interrupted figure-of-eight stitches of silk. The pericardial sac was only loosely closed, so that any excess subsequent collection of fluid could escape into the pleural cavity. It was mandatory to drain the pleural sac for several days after operation so that any accumulation of blood (which might possibly arise from oozing from the chest muscles after the use of heparin) could be quickly evacuated. In all cases, examination of the clotting time showed this to be normal within a few hours after operation.

The appearance in all of the surviving patients of a peculiar postoperative syndrome of transient right-sided heart embarrassment suggests that for some reason there is a period of diminished function of the right ventricle, in spite of the fact that a large burden has been removed from the pulmonary circulation. The mechanism of this phenomenon is obscure and needs further study. It might be related to a hypervolemia, salt retention, or other fluid or electrolyte imbalance of a temporary sort. It tends to correct itself, but doubtless the readjustment could be hastened by appropriate measures if the exact nature of the disturbance were known.

Three general methods for closure of septal defects have been attempted in these patients: (1) by the use of Hufnagel double-disc buttons; (2) by the onlay of plastic sheets to cover septal openings; (3) by direct suture of smaller defects.

1. In 3 patients, with septal openings from 2.5 to 5 centimeters in diameter, lucite or

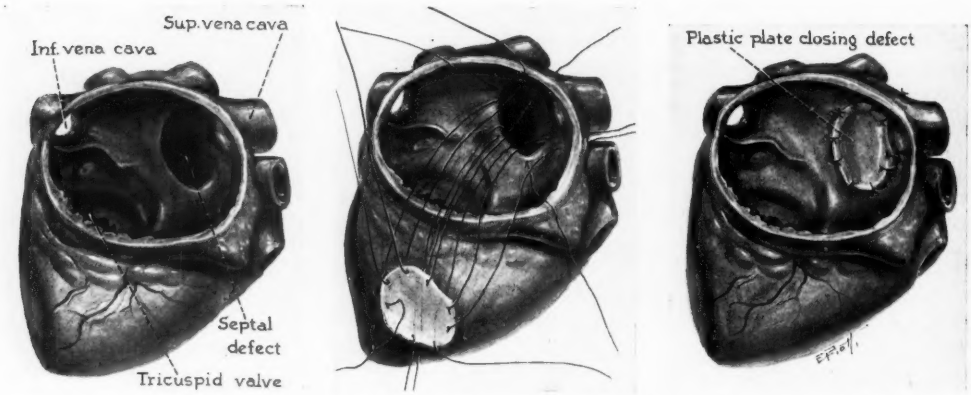

Fig. 17. Method of closure of interauricular septal defect in Case 4, by the application of a nylon sheet. Left, Showing the defect in the superior, posterior portion of the septum, there being an excellent rim of septal tissue inferiorly, but none at the base of the superior vena cava. Middle, All sutures in place. Wherever there is an edge of septal tissue to grasp, sutures are taken through it. Where no such edge exists, sutures are passed out through the atrial wall. Right, Plastic sheet securely anchored into place with silk sutures around its periphery. Where marginal sutures have been placed around the defect, these are tied within the atrium. Where there had been no rim of septal tissue, the sutures which pierce the auricular wall are anchored externally.

kel-F double disc buttons, varying in size from 3 to 4.5 centimeters in diameter, were employed. These choices all proved to be unwise ones. In these first human subjects there was some feeling of haste, and it seemed undesirable to keep the hearts open very long. It was felt that the quick application of a double disc button might put the least strain on the heart, each one of which was known to have had some degree of embarrassment before operation. There was an incomplete rim, or else there was only a very thin substance, around the periphery of the defects; it was impossible to place the buttons in such a way that good tissue could be grasped around their entire circumference. However, it was thought that possibly there was enough available tissue at least to anchor a button in place and provide a baffle which, while not completely occluding the orifice, would greatly cut down the size of the shunt and, therefore, be helpful. As a result of these improper decisions, death occurred in every case. The buttons all worked loose; one fell into the left auricle, another into the right auricle, and one still retained some anchorage at an edge but dropped over into the orifice of the tricuspid valve which it obstructed. In the first 2 cases cited, there was fatality within a few days. In the one wherein the button had obstructed the tricuspid valve there was a rise of pressure in the right auricle which gave a right-left type of shunt through the persisting auricular defect, producing cyanosis (which had not been present before operation). At a second exploration 3 weeks later, the button was retrieved from the interior of the heart and the septal defect closed by direct suture. While the chest was being repaired the patient died. Such disasters would seem to make it evident that the use of these double disc buttons (which can be used so successfully for the occlusion of septal defects in dogs where there is a good rim around the entire periphery of the opening) will probably have very little usefulness in man where septal defects notoriously have incomplete margins and will, therefore, not hold buttons firmly in place.

2. In 3 subjects a septal defect was covered over with a sheet of nylon or polyethylene, sewed to the surrounding structures with interrupted silk stitches. In one of these, the plastic plate was made too large. It completely covered the septal opening but extended too far down over the annulus of the tricuspid valve. The plate had been well anchored posteriorly, superiorly, and anteriorly, but was not tightly tied down to the septum in the

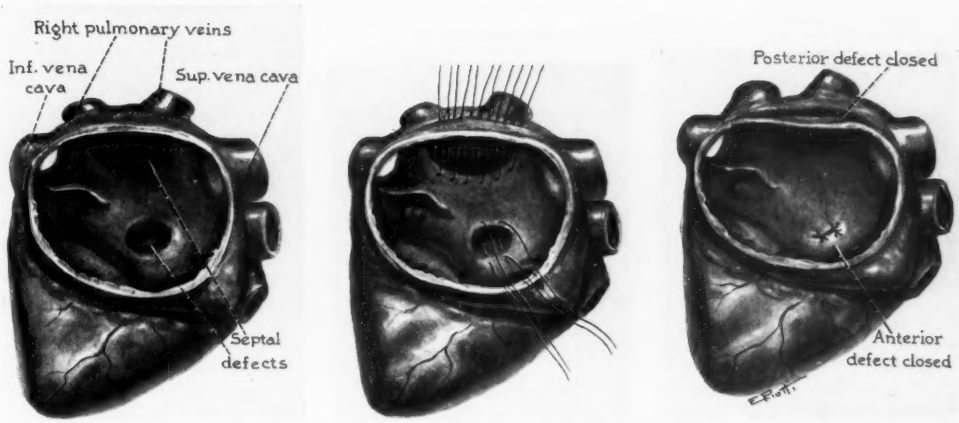

Fig. 18. Closure of interauricular septal defects in patient 5. Two openings were found. Left, There is a long narrow defect toward the posterior portion of the septum, there being no ridge of tissue along the posterior auricular wall. The smaller defect appears in the anterior part of the septum, there being good substance around its entire periphery to allow placement of sutures. Middle, Silk sutures appropriately placed for closure of the two defects. Right, All sutures snugged up and tied, for closure of the two openings.

region just above the annulus. Beneath this raised portion of the plastic plate, there was formation of a blood clot which then propagated downward into the orifice of the tricuspid valve, thereby partially occluding it and leading to death on the third day. In 2 other patients, polyethylene plates of suitable size and shape were fashioned and brought into place to cover the opening completely; they could be accurately held down around their peripheries with interrupted silk stitches (Fig. 17). These 2 children have had extremely satisfactory postoperative courses. Subsequent catheter studies have been performed in 1 of them; it shows the septum to be completely closed.

3. In patient 5, two septal apertures were found (Fig. 18). Because of the relatively small size or narrowness of these, it was decided to attempt primary suture. Various silk stitches were placed as shown in the sketches. Around the smaller anterior opening the tissues were very thin and there was some reason to believe that these might have been torn as the sutures were being tied. With the long, posterior defect there was no rim along the back wall of the atrium. It, therefore, seemed best to grasp the thick margin of septum and to pass the needles out of the back wall of the auricle in a mattress stitch fashion, bringing these sutures to lie just to the right of the right pulmonary veins. Snugging up of these sutures pulled the septal edge backward and also indented the posterior wall of the auricle in a forward direction; the combination apparently completely closed off the area (when examined with an exploring finger). This child has had an amazing recovery. Whereas before she had been in chronic, right-sided heart failure, had marked limitation of activity, an enlarged liver, required digitalization, low salt diet, and other supportive measures, she now appears to be transformed into a different individual. The liver has receded almost to the costal margin. The child greatly enjoys playing tennis, which is an entirely new experience for her.

CASE REPORTS

CASE 1. D.K., an 8 year old girl, was admitted for treatment of congenital cardiac abnormality. At the age of 4 years, she had been hospitalized for ascites and severe congestive failure. At that time the cardiac shadow was found to be enormous. She had been digitalized since that time. There had been retarded physical development and diminished exercise tolerance. Cardiac catheterization had demonstrated conclusive evidence of an interatrial septal defect as well as a normal pulmonary vascular resistance.

Physical examination showed a poorly developed child with prominence of the left precordium. To the left the heart was enlarged to the anterior axillary line. At the apex was a loud systolic murmur and a mid-diastolic rumble; in the pulmonic region was a loud systolic murmur. The pulmonic second sound was duplicated and was much louder than the aortic second sound. The liver edge was palpable 1 centimeter below the costal margin. The neck veins were not distended.

Fluoroscopic examination showed right-sided enlargement of the heart, distinct fullness of the pulmonary artery, and moderate engorgement in the lung fields.

Electrocardiograms showed right bundle branch block and prominent P waves. Fluorescein circulation time was 10 seconds. Venous pressure was 70 millimeters of water.

First operation. On April 3, 1952, right thoracotomy was performed. The chest was opened through a posterolateral incision extending forward beneath the nipple. The pleural space was entered throughout the sixth interspace. The sixth and seventh ribs were divided posteriorly and the fifth and sixth costal cartilages were cut anteriorly; good exposure was obtained. The right auricle was greatly enlarged. There was a faint poorly localized systolic thrill over the heart. A large rubber well was attached to the prominence of the right atrial wall with interrupted No. 0000 Deknatel silk sutures. Although prior to placement of the well, the atrial pressure measured 9.2 centimeters of water by manometer reading, blood rose in the rubber appliance only 5 or 6 centimeters. A defect was found low in the septum, between the posterior atrial wall and the annulus of the tricuspid valve. Not knowing how much of an operative procedure the heart would stand, it was decided to insert a Hufnagel button as quickly as possible. A lucite button 3 centimeters in diameter was positioned. Although the defect had a rather complete rim of septal tissue, this was very thin. The steel prongs of the 3 centimeter button grasped the septal rim only a few millimeters back from the edge of the defect. After closure of the septal defect, the heart diminished greatly in size, and the diffuse thrill disappeared. The well had been open for 12 minutes; it was dismantled and the atrium closed with interrupted figure-of-eight sutures of No. 000 silk. During closure there was evidence of 2:1 atrioventricular blocking, but after closure was completed, the rhythm became normal. The pericardium was closed with interrupted sutures, leaving a defect superiorly for drainage of fluid.

Postoperative course. The initial response was good but within 24 hours there was slight cyanosis of the lips. Cyanosis became worse and was aggravated by exercise. There was progressive evidence of venous congestion, as indicated by distention of the neck veins. Fluorescein circulation time was prolonged to 14 seconds. Arterial oxyhemoglobin saturation was 70 per cent, rising only to 79.4 per cent on inhalation of pure oxygen. The presence of venous congestion and cyanosis, which was not relieved by oxygen inhalation, suggested that the button had become displaced so as to obstruct the tricuspid valve with resultant rise of right atrial pressure and production of a right-to-left shunting of blood through a persistent atrial defect. Fluoroscopic examination confirmed the suspicion that the button had become dislodged from its former position and had migrated to the area of the tricuspid valve. A second intracardiac exploration was carried out in an attempt to retrieve the button and also to attempt closure of the septal defect.

Second operation. On April 28, 1952, in spite of light fibrinous pleural adhesions and a healed suture line on the right atrium, no trouble was encountered in again attaching a large rubber well to the right atrium. Blood rose in the well 4 or 5 centimeters. The button was found to be attached at only one edge of the septal defect, and had flopped over downward and forward to lie within the tricuspid valve orifice. The main portion of the septal defect was open. The button was removed. The 2 centimeter septal defect was then closed by 4 interrupted sutures of No. 000 silk introduced through the well. The well was dismantled and the atrial incision closed with interrupted figure-of-eight sutures of No. 000 silk. As the chest was being repaired, the heart slowed and stopped. After a period of cardiac massage and injection of calcium and adrenalin, ventricular fibrillation was noted. Fibrillation was interrupted by a single electric shock. Synchronized and regular heart beats returned; they gradually increased in vigor. After the chest was closed, the skin color was poor, and peripheral artery pulsations were unobtainable. Within a few minutes a short convulsive seizure occurred, no heart sounds could be heard, and the presence of ventricular fibrillation was proved by electrocardiogram. Shortly thereafter, no electrical tracing could be obtained.

Autopsy. The atrial defect was completely closed by silk sutures. One suture had partially torn through the thin septal edge, but this did not compromise the closure. There were hemorrhages in the myocardium, lungs, subarachnoid space, and subdural space.

CASE 2. M.Z. was a 4 year old female. At the age of 7 months she was known to have a heart murmur. At 2 years, studies revealed right-sided cardiac enlargement and a moderate congestive failure, with basilar rales and a palpable spleen. She was maintained in a satisfactory manner by means of digitalization, a low salt diet, and occasional mercurial diuresis. She grew fairly well during this regimen. Her activity was not limited. There was no history of cyanosis.

Examination showed a slightly underdeveloped child in no distress. There was increased prominence of the left precordium. The apical cardiac impulse was 6 centimeters to the left of the midclavicular line. The apical first sound was accentuated and the pulmonic second sound was split. Prominent sys-

tolic murmurs were audible at the apex and in the pulmonic region, and there was an apical mid-diastolic rumble. The neck veins were distended. The spleen and liver were enlarged.

Fluoroscopic examination of the heart showed right ventricular enlargement. The auricles and the pulmonary artery were prominent. There was pulmonary vascular engorgement and a hilar dance.

Cardiac catheterization demonstrated the presence of an atrial left-to-right shunt of 6.7 liters per minute. The systemic flow was 3.3 liters per minute. Pulmonary vascular resistance was normal. Electrocardiograms showed right ventricular hypertrophy and right bundle branch block with prominent P waves. Fluorescein circulation time was 10 seconds.

Operation. Right thoracotomy was performed on April 3, 1952. The right atrium and right ventricle were hypertrophied and dilated. Pulmonary engorgement was pronounced. A large rubber well was attached to the right atrium. Although the atrial pressure prior to placement of the well had measured 20 centimeters of water, after attachment of the well and tilting the body 30 degrees with the legs downward, blood rose in the rubber well only 5 or 6 centimeters. A 2 centimeter defect was found low on the auricular septum. There was an incomplete rim of septal tissue around this. When the defect was partially occluded with two fingers, cardiac irregularity and weakened contractions were noted. It was deemed advisable to terminate the procedure rapidly by insertion of a Hufnagel button. A 3 centimeter lucite button was inserted so that there was no impingement on the coronary sinus or tricuspid annulus, and the atrium was closed after being open for 15 minutes. After closure of the defect, the heart decreased greatly in size. Its activity was markedly reduced as compared to its previous vigorous contractions. Pulmonary engorgement markedly diminished. Immediately after operation, the patient was in rather precarious condition. The radial pulse was only fair. The skin color was satisfactory.

Postoperative course. During the first 24 hours the patient responded but her course was unsatisfactory. The blood pressure remained low and in spite of transfusion and adequate intake of fluid, the urinary output was depressed to less than 400 cubic centimeters per 24 hours. A soft systolic murmur was audible just to the left of the sternum and a gallop rhythm was heard. Electrocardiogram on the second postoperative day showed high peaked T waves. Serum potassium at that time was 6.7 millequivalents per liter and serum sodium was 121 millequivalents per liter. By x-ray film, the button had obviously shifted its position and was apparently lying in the right atrium. Evidence of congestive failure became worse, as manifested by progressive distention of neck veins, hepatic enlargement, and appearance of basilar rales. She expired on the third postoperative day. Permission for autopsy could not be obtained.

CASE 3. D.C. was an 8 year old girl who was known to have congenital heart disease since birth. There had been cyanosis in the neonatal period but none since then. The child had always been considered to be "delicate." Activity was normal although she tired very easily. There was no history suggesting congestive failure.

On examination she was undernourished. The heart was enlarged to the left anterior axillary line. There was a loud systolic murmur in the pulmonic region and a systolic murmur and systolic click at the apex. The pulmonic second sound was split. The spleen was palpable and the liver could be felt 4 centimeters below the costal margin. The neck veins were distended.

Roentgenograms of the chest showed enlargement of the right ventricle and both auricles, dilatation of the pulmonary artery, pulmonary vascular engorgement, and a hilar dance.

Cardiac catheterization showed enormous left-to-right atrial shunting (16.4 liters per minute), a systemic flow of 2.74 liters per minute per square meter body surface area, and normal pulmonary vascular resistance. Electrocardiogram showed right ventricular hypertrophy with right bundle branch block. Fluorescein circulation time was 11 seconds.

Operation. On April 11, 1952, a right thoracotomy showed cardiac enlargement, distention of the vessels of the lung root, and a systolic thrill over the hilum of the lung. A large rubber well was attached to the side of the distended right atrium and blood rose within it to a level of 7 or 8 centimeters. There was an enormous atrial defect measuring 4.5 by 5 centimeters. This lay high in the septum so that there was a margin of septal tissue inferiorly and anteriorly but none superiorly and posteriorly. An attempt was made to pass a 5 centimeter kel-F button in the auricle, but it could not be manipulated into place. A 4.5 centimeter button was positioned and although septal tissue could be grasped at the rim inferiorly and anteriorly, a closure could not be obtained superiorly; this left a crescentic defect where the rim was absent. This was regarded as an unsatisfactory button placement, but it was hoped that at least a baffle would be created which would greatly reduce the size of the shunt. The well had been kept open for 30 minutes.

Postoperative course. Shortly after operation cyanosis appeared. Signs of progressive congestive failure became evident with dyspnea, tachycardia, diffuse crepitant rales, and increasing enlargement of the liver. In spite of rapid digitalization the child's course was progressively downhill. She expired on the third day.

Autopsy. Examination showed complete dislodgement of the button; it lay free within the left atrium. There were 300 cubic centimeters of sanguineous fluid in the right pleural space. There was marked passive congestion of the various viscera.

CASE 4. G.S., a boy of 9, was admitted because of shortness of breath on exertion. At 1½ years of age,

Fig. 19. Patient 4, four months after surgical treatment of interauricular septal defect. Cardiac catheterization shows that the septum is completely closed.

a systolic murmur had been heard. At previous hospital admissions, roentgen examination had shown right ventricular enlargement and pulmonary vascular engorgement. In 1950 cardiac catheterization had demonstrated the presence of an atrial left-to-right shunt flow of 7.1 liters per minute. There was no pulmonary vascular obstruction at that time. Electrocardiogram demonstrated right ventricular hypertrophy and right bundle branch block.

Physical examination showed a rather thin boy. There was prominence of the left precordium. The apex beat was at the anterior axillary line. There was a loud systolic murmur in the pulmonic region and a soft diastolic murmur at the apex. The mitral first sound was split. The liver and spleen were not enlarged.

By T-1824 dye solution the plasma volume was 73 milliliters per kilogram; the blood volume was 129 milliliters per kilogram. Fluorescein circulation time was 10 seconds.

Operation. Findings at right thoracotomy on April 15, 1952, included right atrial and right ventricular enlargement, pulmonary vascular engorgement, and a hilar thrill. A rubber well was attached to the right auricle; blood rose 6 centimeters into it. A septal defect measuring 3 by 2 centimeters was found high and posterior in the septum (Fig. 17). This opening had no rim of tissue at the orifice of the superior vena cava. A disc of nylon sheet, 0.81 millimeter thick, was cut to the dimensions of the defect and was secured to silk sutures which were to be used for anchoring it into place. Seven of the sutures grasped the rim of septal tissue anteriorly and inferiorly, while 3 of them were passed out from the auricular cavity through the atrial wall in those regions where no septal rim was present. The disc was introduced into the heart, obliterating the defect, and was anchored into place by tying the various sutures. The well had been kept open for 47 minutes. The procedure was well tolerated.

Postoperative course. For a few days after operation there was mild right-sided heart failure, as evidenced by slight elevation of venous pressure, prolongation of circulation time to 13.5 seconds, expansion of the plasma volume to 98 milliliters per kilogram, and tender enlargement of the liver. The patient began to walk on the fourth day. Easy fatigability diminished and he was discharged on the thirteenth postoperative day, showing steady disappearance of the congestive signs.

Subsequent course. The boy was readmitted to the hospital for re-evaluation on June 2, 1952. In the interval he had been able to return to school and ride his bicycle with ease. The left cardiac border remained in the mid-clavicular line. There was a loud third heart sound, and a soft blowing systolic murmur at the apex and at the left sternal border. There was a pericardial friction rub in the second and third left interspaces. The liver had decreased in size and was palpable 1 centimeter below the costal margin. Fluoroscopic examination showed some reduction of pulmonary vascular markings.

Cardiac catheterization showed complete closure of the septal defect. It was possible to pass the catheter from the root of the superior cava into a right pulmonary vein. The finding suggests that the nylon disc has been located in the region of the vein root in such a manner that it lies astride the vein orifice so that a portion of the pulmonary venous drainage is directed into the right auricle. If this explanation is not correct, there must be an anomalous small pulmonary vein entering the right auricle. This small shunt flow of 0.75 liters per minute is in contrast to the preoperative left-right shunt flow value of 7.1 liters per minute. One striking finding of the postoperative catheterization is the fact that rather than the pulmonary artery flow and systemic flow being reduced, the pulmonary artery flow has remained elevated at 10 liters per minute as contrasted to a preoperative value of 9.8 liters per minute, while the systemic flow has shown an elevation from 3.4 liters per square meter per minute to 9.5 liters per square meter per minute. The cause of this elevation of left ventricular output is obscure and cannot be accounted for on the basis of any apparent error in the catheterization technique. There is no evidence of chronic venous congestion in response to high output since the right auricular pressure has fallen following operation from a mean value of 10 millimeters of mercury to 4 millimeters of mercury, and the pulmonary "capillary" pressure has fallen from 13 millimeters of mercury to 7 milli-

meters of mercury in spite of the threefold increase in left ventricular output. The plasma volume has fallen from a preoperative value of 73 milliliters per kilogram to 59 milliliters per kilogram.

CASE 5. G.C. was a 14 year old girl, on whom a diagnosis of atrial septal defect had been made 3 years previously by cardiac catheterization. When she was 6, a heart murmur had been heard, and after the age of 11 she was noticed to be slightly cyanotic and also short of breath after exertion.

Physical examination showed a pulmonic systolic murmur and an apical mid-diastolic rumble. There was no cyanosis or clubbing.

Roentgen examination revealed enlargement of the right side of the heart and marked pulmonary vascular engorgement.

By electrocardiogram, a right bundle branch block was present.

Cardiac catheterization showed: (1) a left-to-right atrial shunt flow of 14 liters per minute; (2) depression of systemic flow index (2.3 liters); and (3) normal pulmonary vascular resistance. Fluorescein circulation time was 10 seconds. Venous pressure was 80 millimeters of water. By T-1824 dye dilution, the plasma volume was 60 milliliters per kilogram, the blood volume was 103 milliliters per kilogram.

Operation. A right thoracotomy was performed on April 16, 1952. The right auricle and ventricle were greatly enlarged. A systolic thrill could be felt in the dilated vessels at the lung root. A large rubber well was secured to the atrial wall with 20 sutures. The heart action was weak during application of the well and the arterial pressure fell to 60 millimeters systolic. On opening the well, blood rose 11 centimeters into it. Two defects were found in the atrial septum (Fig. 18). A small round orifice 1 centimeter in diameter occupied the central portion of the septum. In the posterior part of the septum there was an elongated opening 5 centimeters long and 1 centimeter wide. This lay just anterior to the orifices of the right pulmonary veins, without any ridge of septal tissue along the posterior margin of the atria. Two sutures of No. 000 Deknatel, placed and tied through the well, were used to close the small central defect, the thinness of the septal tissue raised some doubts whether these would hold. The absence of any ridge of septum along the posterior margin of the larger defect prevented suture being placed entirely within the auricle. Straight needles, carrying No. 000 Deknatel silk, were introduced through the back wall of the right auricle just to the right of the pulmonary veins. With a directing finger immersed in the well, these needles were guided to grasp the edge of the septal margin. The needles were retrieved through the rubber well, and then were passed out of the back wall of the auricle as mattress stitches. Tying up these mattress sutures obliterated the septal opening by pulling the septal rim to the back wall of the atrium, just to the right of the pulmonary veins. The heart action improved during this procedure. Following closure of the second defect, blood in the well became darker and the heart decreased in size. The well was removed and the atrium was closed with interrupted figure-of-eight silk sutures. The well had been open 53 minutes.

Postoperative course. Recovery from anesthesia was prompt and blood pressure stabilized at 115/70 millimeters of mercury 6 hours after operation. Four hours after operation, the blood coagulation time was 5 minutes. Appreciable amounts of sanguineous fluid could be aspirated from the chest during the first 6 days, following which the intercostal catheter was withdrawn. Roentgen examination showed definite reduction in the pulmonary vascular markings. During the first postoperative week, there was evidence suggestive of mild right-sided failure. The liver edge became palpable 3 centimeters below the costal margin; it was tender. The urinary output was low, there was slight elevation of venous pressure, and there was tachycardia. These findings gradually disappeared. The patient walked on the fifth postoperative day and was discharged on the eleventh day.

Subsequent course. The patient was readmitted for study on June 2, 1952. In the interim she had noticed subjective improvement in that she did not "puff" as much as before operation. Activity had been somewhat limited during this period. There was a soft systolic murmur at the apex and under the left clavicle. The liver was palpable 2 centimeters below the costal margin but was not tender. Cardiac catheterization showed some persistence of left-to-right atrial shunting. The volume of shunt flow had decreased from a preoperative value of 14 liters per minute to a volume of 4.7 liters per minute. No conclusions could be drawn concerning which of the two septal defects had the residual opening. The catheter could not be passed into the left auricle, in spite of repeated efforts to do this. Systemic flow showed an elevation from a preoperative figure of 2.3 liters to 2.8 liters per minute per square meter body surface area. The right auricular pressure had fallen from a preoperative mean value of 11 millimeters of mercury to 3 millimeters of mercury. Pulmonary "capillary" pressure had fallen from 17 millimeters of mercury to 8 millimeters of mercury. The plasma volume was 58 milliliters per kilogram

Four months after operation this child appears to be in excellent health. She is most exuberant. She likes to play tennis and engage in other strenuous sports—all of which are entirely new experiences for her.

CASE 6. W.R. was a 16 year old boy who had marked fatigability on exertion. At 12 years a murmur had been detected. At 15 years, roentgenograms had shown enlargement of the heart. At that time an electrocardiogram demonstrated frequent ventricular premature contractions.

Physical examination showed a well nourished and well developed boy without signs of congestive failure. The left precordium was quite prominent. The heart was enlarged to the anterior axillary line and

there was a heaving cardiac thrust. There was a harsh apical systolic murmur and a low-pitched systolic murmur along the left sternal border. There was a high-pitched early diastolic murmur along the left side of the sternum. The pulmonic and aortic second sounds were duplicated.

Cardiac fluoroscopy showed a large heart with predominantly right ventricular enlargement, enlarged auricles, prominence of the pulmonary conus, pulmonary vascular engorgement, and a hilar dance.

Cardiac catheterization showed a left-to-right shunt flow through a very large atrial defect (14 liters per minute per square meter body surface), a systemic flow of 3.8 liters per minute per square meter body surface and a reduced pulmonary vascular resistance. Electrocardiogram showed a regular rhythm and right bundle branch block.

Operation. At the time of right thoracotomy on April 26, 1952, the lung substance was found to be greatly engorged and the pulmonary vessels enormously distended. There was a thrill in the hilum of the lung. The heart was enlarged, the right atrium being particularly prominent. A large rubber well was attached to the right auricle; blood rose 8 centimeters into it. Except for a small ridge of septal tissue at the superior caval orifice, the atrial septum was absent. Essentially, there was a common atrium, the opening between the two sides being about 5 centimeters in diameter. An oval sheet of polyethylene, 0.5 millimeter thick, was cut about 5 centimeters wide and 7 centimeters long. Seventeen sutures were introduced through the well into the septal margin of the tricuspid valve ring and the superior septal ridge, or were passed out through the auricular wall in those areas where there was no septal substance to grasp. These various silk stitches were passed through the margins of the polyethylene sheet which was then pushed down into place, and the stitches were tied. Digital palpation of the anchored sheet disclosed that the septal defect was completely closed over, but that the piece of plastic was too long and, therefore, projected down over the annulus of the tricuspid valve. We were loath to remove it or to attempt cutting off its lower end. The heart decreased in size and the pulmonary engorgement diminished after closure of the defect. During the prolonged intracardiac manipulations, the cardiac rhythm was remarkably regular. The well had been kept open 2 hours and 5 minutes.

Postoperative course. Recovery from anesthesia was prompt and the blood pressure stabilized around 110/50 within a few hours. All electrocardiograms taken after operation demonstrated the presence of an auriculoventricular nodal rhythm. The patient was unusually listless. The skin was sallow but there was no scleral icterus. The urinary output was depressed. The venous pressure was elevated to 160 to 170 millimeters of saline. On the morning of the third postoperative day the patient had a sudden spell of gasping respiration and then died.

Autopsy. Examination showed that the septal defect had been effectually closed, but a clot had formed beneath the excess portion of the polyethylene plate. This clot had propagated down into the tricuspid orifice and partially occluded it.

CASE 7. S.W. was an underdeveloped girl of 11 years. She was born prematurely, weighing 2 pounds at birth. There was early retardation of growth and slow mental development. There was marked limitation of tolerance to physical exercise. She could walk only about half a block before tiring. There were no complaints suggestive of congestive failure.

Physical examination showed a thin child appearing about 6 or 7 years of age. There was left-sided prominence of the chest and a heaving cardiac impulse. The apical beat was in the left midclavicular line. There was a high-pitched early systolic murmur in the second left interspace and a questionable early diastolic murmur in the fourth left interspace. The pulmonic second sound was split. The neck veins were slightly distended and the liver was palpable 2.5 centimeters below the costal margin.

Electrocardiograms showed incomplete right bundle branch block and a normal cardiac axis. Fluoroscopy showed that the heart was considerably enlarged with predominance of the right ventricle. The right auricle was moderately enlarged. The pulmonary artery was prominent and the pulmonary vascular markings were distinctly increased.

Catheterization showed left-to-right interatrial shunting (8.3 liters per minute), a systemic flow index of 4.6 liters, normal pulmonary vascular resistance, and a rather wide systemic arterial pulse pressure (femoral arterial pressure 140/80). By the T-1824 dye dilution method, the plasma volume was 67.4 cubic centimeters per kilogram, the blood volume was 109 cubic centimeters per kilogram.

Operation. On June 30, 1952, a right thoracotomy was performed. The right auricle and ventricle were found enlarged. A systolic thrill was palpable over the right pulmonary hilum. A large rubber well was attached to the side of the right atrium and the atrium opened widely. A large, oval defect occupied the central portion of the atrial septum; this measured 3 by 2.5 centimeters. There was a narrow rim of septal tissue around the periphery of the defect. A sheet of polyethylene plastic (0.51 mm. thick) was cut to dimensions similar to the estimated size of the defect and to its approximate contour. With silk sutures around its periphery the disc was then anchored to the septum to lie over and close the defect. All sutures were located in the septal rim by introduction through the well. Nine sutures were employed to hold the polyethylene in place. Digital examination showed the defect to be completely obliterated by this prosthesis. The well had been kept open 40 minutes.

Postoperative course. Immediately following operation the blood pressure was 80 systolic, 50 diastolic, pulse rate 125, and rectal temperature 92 degrees F. The pulse was strong and skin color good. Within a few hours, the temperature rose to normal and the patient's general status was satisfactory. During succeeding days the course was extremely smooth.

The patient walked on the seventh postoperative day. At no time after operation was there evidence of cardiac congestion. The liver has not been enlarged. On the tenth postoperative day, plasma volume was 67.0 cubic centimeters per kilogram and blood volume 108 cubic centimeters per kilogram of body weight. The pulmonic murmur has greatly diminished in intensity. The child was discharged from the hospital in 2 weeks, and at that time appeared to be in very satisfactory condition.

SUMMARY AND CONCLUSIONS

A method has been devised whereby it is possible to attach a rubber well to the right auricle so that the atrium can be opened into this well, thereby providing direct access into the interior of the chamber. This appliance can be left in place for a rather indefinite period of time and intracardiac manipulations can be carried out with precision and great accuracy. With its aid, interauricular septal defects can be felt with the exploring finger and knowledge can be accumulated regarding the size, shape, and position of the opening as well as the nature of the margins which surround the orifice.

With an atrial well approach to the interior of the heart, large interauricular septal defects can be closed by carrying into place a sheet of plastic material which covers the opening and which is securely held in position by sutures which anchor it to remaining rims of septum or to nearby surfaces of the auricular wall. Small defects can be closed by direct suture.

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RETROGRADE INTRAMURAL SPREAD OF CARCINOMA OF THE RECTUM AND RECTOSIGMOID

A Microscopic Study

ERICH A. QUER, M.D., DAVID C. DAHLIN, M.D., and
CHARLES W. MAYO, M.D., F.A.C.S., Rochester, Minnesota

CONSIDERABLE difference of opinion exists among surgeons regarding the extent of distal intramural spread of carcinoma in the rectosigmoid and rectum. The practical outcome is that some surgeons, in conformity with the ideas of greatly restricted intramural spread, remove the growth together with comparatively little free edge below the lesion and content themselves with restoring the continuity of the bowel by end-to-end anastomosis whenever possible; other surgeons, impressed with the idea of extensive intramural dissemination, remove a considerable portion of bowel and, of necessity, create an artificial stoma.

Many investigations have been undertaken to determine the extrarectal retrograde and lateral spread of carcinoma arising in these regions. Most of these studies have shown that spread in this mode is rather infrequent and is usually present only in those cases in which the upward lymphatic pathways have been blocked. It also has been shown that surgeons who utilize operations which restore normal continuity of the bowel remove as much of the lateral and upward zones of nodal tissue as do those surgeons utilizing the combined abdominoperineal operation of Miles.

It is, therefore, imperative that the extent of retrograde intramural spread be clarified by microscopic examination so that the surgeon will know how much grossly uninvolved intestinal wall he must remove below the lesion to make the operation for cancer adequate. To obtain practical data bearing on the problem, too much dependence must not be placed on opinions derived merely from clinical observations nor on postmortem material in which the picture is blurred by advanced changes and associated secondary inflammatory processes. This issue can be decided only in cases in which the lesions are still operable in the hope of cure.

Because of these facts and the many conflicting reports in the literature often based on small series of cases or inadequate microscopic examinations, the present detailed study was undertaken.

From the Department of Surgery (Fellow), Mayo Foundation, University of Minnesota, and the Divisions of Surgical Pathology and Surgery, Mayo Clinic.

Abridgment of portion of thesis submitted by Dr. Quer to the Faculty of the Graduate School of the University of Minnesota in partial fulfillment of the requirements for the degree of Master of Science in Surgery.

HISTORICAL REVIEW

Clogg, in 1904, was apparently the first to study this subject in 25 cases, and he was unable to demonstrate spread of the growth in the colon "similar to that which occurs in the stomach." In 1910, Handley made longitudinal strips along the whole length of the excised bowel in 10 cases. He found what he interpreted as intramural lymphatic permeation of cancer cells both proximal and distal to the lesion for considerable distances in 2 cases but concluded that it must occur in many more cases. Cripps and others took sharp issue with this in 1912 and stated emphatically that "amongst the most successful cases are those operations in which perhaps only one-half inch margin is allowed." In 1913, Cole found no evidence of permeation beyond the microscopic edge of the growth in 19 cases. Miles, in 1920 and again in 1931, concluded from clinical, as well as histologic studies, that intramural spread is always of comparatively trivial extent. Westhues, in 1934, found only 1 instance of intramural spread in 74 cases studied and this lesion showed only proximal spread

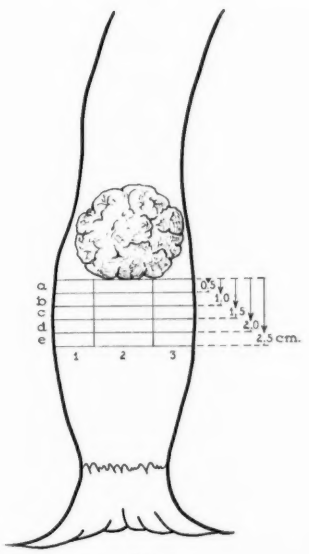

Fig. 1.

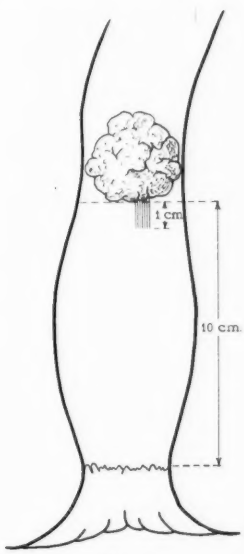

Fig. 2.

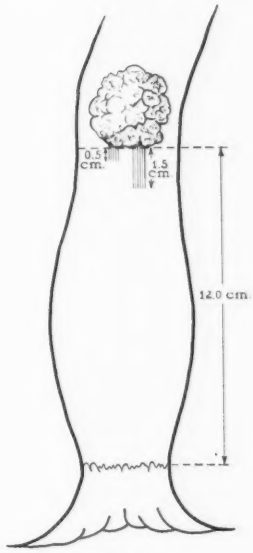

Fig. 3.

Fig. 1. Method by which the bowel was sectioned serially below the lesion and by which the blocks were identified.

Fig. 2. Case 1. Shaded area represents extent of retrograde spread in the one involved submucosal vein.

Fig. 3. Case 2. Shaded area represents extent of retrograde spread in the two involved submucosal veins.

for a distance of 3 centimeters. Black, in studying microscopically one block above and one block below the lesion, found intramural spread of 5 millimeters or more in 4 of 103 cases, the farthest being 12 millimeters. Dukes and others were also impressed with the limited extent of intramural spread both above and below the lesion. Clinical evidence to support the rarity of significant spread was supplied by Gordon-Watson in 1938, who found no recurrences in the rectal stump left after the Hartman operation. Winkler, on the other hand, was of the opinion that carcinoma of the colon spread intramurally both distal and proximal for distances up to 8 centimeters, and this accounted for the recurrences. In 1949, Connell and Rottino startled everyone when they reported the finding of significant retrograde intramural spread in 4 of 9 cases studied by a modified serial section technique of the entire circumference of the bowel.

MATERIAL AND METHODS

Ninety-one consecutive fresh operative specimens of adenocarcinoma of the rectum and rectosigmoid which fulfilled the following rigid criteria were selected for this study: (1) The lowest level of the lesion had to be located not less than 5 centimeters, or more than 15 centimeters, from the dentate line, as determined by proctoscopic and gross measurements. (2) The specimen removed had to contain at least 3 centimeters of the entire thickness of the wall of the bowel below this lesion. (3) The surgeon must have felt certain that the operation was curative and not palliative.

TABLE I.—RETROGRADE INTRAMURAL SPREAD

Case No.	Grade of lesion	Dukes' type	Retrograde spread			
			Type of spread	Extent below lesion, cm.	Site	Continuity
1	2	B	Venous	To 1	Submucosa	Yes
2	2	B	Venous	To 0.5 and 1.5	Submucosa	Yes
3	3	C	Lymphatic	To 5	All layers	Yes
4	3	C	Lymphatic	From 7.2-9	Muscularis externa	No
5	2	B	Implant (?)	From 5-6	Mucosa	No

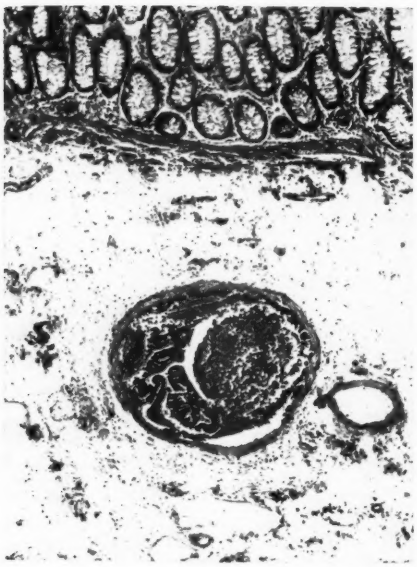

Fig. 4. One of the involved submucosal veins. Veins of this type were seen in Cases 1 and 2. Hematoxylin and eosin, ×45.

Whenever distant metastasis or unremoved local extension was suspected on roentgen examination or on gross examination at operation, the tissue removed was not utilized for study. Specimens from patients treated by either anterior resection or combined abdominoperineal resection were used so long as they fulfilled the criteria just listed. Each of the 91 specimens was obtained directly from the operating table at which time all clinical, proctologic, roentgenologic, and laboratory records were again reviewed and the surgeon was questioned carefully about the condition of the liver, peritoneal surfaces, surrounding structures, and distant lymph nodes. The specimen was immediately opened and pinned out on a suitable board. To obviate shrinkage, the specimen was stretched to conform with the preoperative or operative measurements of length or both and was then immediately fixed for 48 hours in 10 per cent formalin. Then a full scale drawing was made of the whole specimen noting surrounding polyps and mucosal characteristics. The entire circumference of the bowel was sectioned serially at 5 millimeter intervals for a distance of 2.5 centimeters below the lesion (Fig. 1), and mounted microscopic sections were made from the cephalad surface of each block. Sections were recut whenever any doubt about their perfectness existed. The slides thus obtained were carefully examined microscopically with the aid of a mechanical stage. The 91 specimens showed the following features: 32 contained malignant lesions of grade 1 (Broders' method); 51, grade 2; 7, grade 3; and 1, grade 4. By Dukes' classification 1 lesion was classed as type A, 58 as type B and, 32 as type C. Forty-three lesions were 5 to 10 centimeters from the dentate line and 48 were 10 to 15 centimeters from it.

RESULTS OF STUDY

Retrograde intramural spread was found in 5 of these 91 cases (Table I). The lesions in Cases 1 and 2 were rather unique in that they were both of a low degree of malignancy (Broders' grade 2), were of very limited local extent, were without lymphatic or serosal involvement, yet had retrograde intramural extension. This extension, however, was for a short distance only and occurred in submucosal veins rather than in lymphatic channels. Why there should have been any retrograde intramural venous spread is difficult to ascertain. Figures 2 and 3 show diagrammatically, and Figure 4 microscopically, the extent and location of the spread in these submucosal veins. It will be noted that in Case 2, the spread was present in 2 areas.

In Case 3, a rather unfavorable lesion was present from many standpoints. It was of high grade malignancy (Broders' grade 3), and there was extensive local involvement as well as extensive involvement of perineural lymphatics, lymph channels, and lymph nodes. The extent of the distal intramural spread is shown graphically in Figure 5. It was present in all layers of the bowel and seemed to be confined to lymph channels (Fig. 6).

The lesion in Case 4 was also of grade 3 malignancy, and showed extensive venous, serosal, and lymphatic involvement. It is peculiar in that the distal intramural spread was not in continuity. A metastatic nodule, about 1.5 centimeters in diameter, was found in the muscularis externa 7.2 centimeters below the

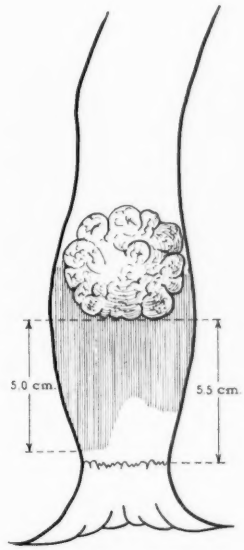

Fig. 5. Case 3. Shaded area represents extent of retrograde spread in all layers of intestinal wall.

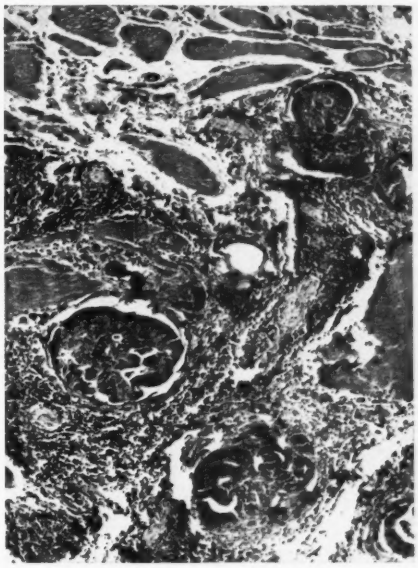

Fig. 6. Lymphatic channels of muscularis externa filled with malignant cells. Hematoxylin and eosin, ×60.

primary lesion (Figs. 7 and 8). It is interesting to speculate how this metastasis occurred. Dukes and Bussey have shown by their studies that these secondary tumors are due to continuous growth along the hemorrhoidal vessels and extension into the intramural vessels. This permeation of the veins, in the direction opposite to the natural flow of blood, results in the re-eruption of carcinomatous deposits in the intestinal wall often at a considerable distance above or below the tumor. This peculiar manifestation they found only in about 5 per cent of cases in which there is evidence of intravascular growth. With extensive blockage of the proximal lymph channels, as in this case, extramural retrograde lymphatic spread by permeation or embolization and re-eruption into the intestinal wall also could explain this picture. This intramural nodule was easily palpable on rectal digital examination and was visualized on proctoscopic examination. It certainly would not have been left behind in any planned surgical procedure.

Case 5 is extremely interesting and most certainly very unusual. The lesion of grade 2 malignancy showed practically no local extension and there was no venous, serosal, or lymphatic involvement, yet a metastatic lesion was found in the mucosa at the dentate line 5 centimeters below the main lesion (Fig. 9). This spread was not in continuity and had the appearance of an implant (Fig. 10). Three months prior to her combined abdominoperineal resection, the patient had had a hemorrhoidectomy elsewhere without relief from her rectal bleeding. Since the primary lesion was an almost annular, ulcerating adenocarcinoma, it is almost certain that it was present at the time of the hemorrhoidectomy. This retrograde spread may represent drop metastasis from the parent tumor which implanted on the raw surface at the site of the hemorrhoidectomy. This lesion too was observed preoperatively and would certainly also not have been left behind in any planned surgical procedure for carcinoma.

COMMENT

As pointed out previously, we considered it extremely important that our series consist only of patients who exhibit removable cancer

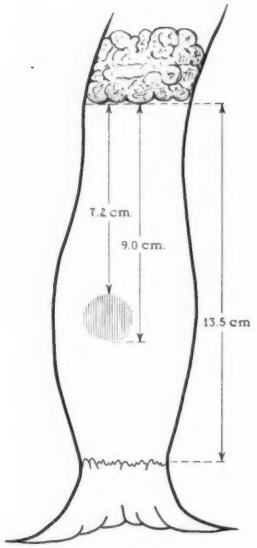

Fig. 7. Case 4. Shaded area depicts metastatic intramural nodule.

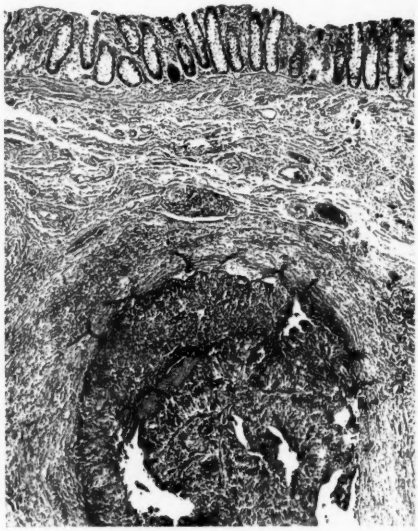

Fig. 8. Case 4. Portion of intramural nodule. Hematoxylin and eosin, ×30.

deposits since this group may be treated successfully. The status of the intestinal wall below the carcinoma is of little importance when incurable lesions are present. We did, however, not limit our selection to just small or low grade lesions, but chose consecutive lesions similar to the general run of cancers which are removed at operation from this region. In 35 per cent of our cases the malignancy of the lesion was grade 1, and in 56 per cent grade 2, whereas in 63 per cent the extent of spread was of the Dukes' type B, and in 36 per cent lymph nodes were involved (Dukes' type C). We also consider that a series of 91 cases is large enough to be significant.

In choosing our method for this study we obviated the possibility of erroneous measurements because of shrinkage due to formalin fixation. We also obviated the possibility of missing any instances of continuous retrograde extension by sectioning the whole circumference of the bowel rather than only longitudinal strips. If such strips were sectioned or if random microscopic sections were made, the result might well be that retrograde spread of the type which is depicted in Figures 2 and 3 would be missed.

An analysis of our results shows rather conclusively that significant retrograde intramural spread occurs rarely and, when present, is of little importance except in an occasional case. In that rare instance, there is almost always extensive involvement of perirectal structures, serosal surfaces, veins, perineural lymphatics, lymphatic channels, and lymph nodes.

The all important question that remains to be answered is how much grossly uninvolved intestinal wall must be removed below the lesion to make the operation adequate. Dunphy and Broderick, in criticizing measurements obtained by studies on formalin-fixed specimens, recommended an operative margin of safety of 10 centimeters. Others, on the basis of their own investigations or a review of other studies or both, have recommended margins varying from 2 to 10 centimeters, and often even more. Some, however, condemn the use of low anterior resections for treating carcinomatous lesions in these regions.

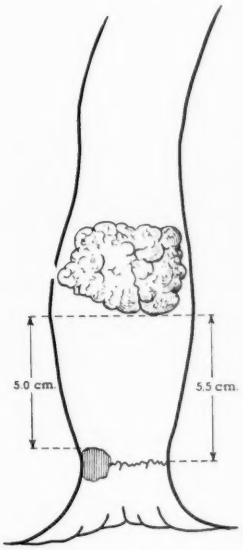

Fig. 9. Case 5. Shaded area depicts retrograde mucosal implant.

On the basis of our results, it can be recommended that from the standpoint of retrograde intramural spread a margin of 2.5 to 3 centimeters of grossly uninvolved intestinal wall below the lowest grossly palpable or visible edge of the carcinoma is sufficient to make the operation adequate. Eighty-eight of our 91 patients could have been treated successfully by removal of that much distal intestinal wall.

Cases 4 and 5 might well be excluded because of the peculiar nature of the retrograde spread and the fact that the spread was diagnosed clinically, with the result that adequate surgical procedures were employed to cope with these special findings. Excluding these, a margin of even 2 centimeters would have been sufficient to treat 88 of the 89 patients. In Case 3, the only case in which this margin would have been insufficient, low anterior resection would never have been employed not only because of the high grade of the lesion and the extensive involvement of the veins and perirectal and lymphatic structures, but also because of the technical aspects of such a low-lying lesion in a deep male pelvis.

Fig. 10. Case 5. Mucosal implant. Adjacent squamous cell epithelium of anus may be noted. Hematoxylin and eosin, ×40.

CONCLUSIONS

The following conclusions seem warranted:

1. Distal intramural spread of a significant degree is rarely a problem in the management of operable carcinomas in which the lower edges lie from 5 to 15 centimeters above the dentate line. If the 2 patients who had clinically obvious metastatic deposits are excluded only 1 of 89 patients had retrograde spread beyond 1.5 centimeters, and 86 had no retrograde intramural spread.

2. A margin of 2.5 centimeters of grossly uninvolved intestinal wall below the lowest grossly palpable or visible edge of the carcinoma is sufficient to make the operation adequate from the standpoint of retrograde intramural spread when lesions of low grade of malignancy (Broders' grade 1 or 2) are present.

3. Lesions of high grade of malignancy (Broders' grade 3 or 4) are best not treated by a low anterior resection unless a margin of 6 centimeters or more can be allowed.

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RESULTS IN THE TREATMENT OF CARCINOMA OF THE COLON AND RECTUM

An Analysis of 2,341 Cases over a 35 Year Period with 5 Year Survival Results in 1,667 Patients

ROBERT S. GRINNELL, M.D., F.A.C.S., New York, New York

THE purpose of this study is to review the results and the general trend in the treatment of carcinoma of the colon and rectum at the Presbyterian Hospital, New York, from 1916 to 1945 inclusive. All tumors removed by ileocolectomy and colectomy and all those removed by anterior resection or anterior excision with colostomy (Hartmann) have been classed as colon lesions, irrespective of their location. Tumors removed by abdominoperineal resection, perineal and sacral proctectomy, and by abdominoanal pull-through procedures have been classed as rectal lesions. Tumors lying 13 centimeters or more from the anal margin which were removed by local excision or treated by palliative surgery have been put in the colon group, whereas those lying 12 centimeters or less from the anal margin have been classed as rectal lesions.

In the past 35 years there has been an increasingly radical surgical attack on carcinoma of the large bowel. More of these tumors are being resected than previously and fewer palliative procedures, such as colostomy and side-tracking operations, are being done. The resectability rate has shown a steady rise with an accompanying fall in operative mortality. In addition to the tumor itself, contiguous structures and contact organs, such as adherent loops of intestine, the uterus and its appendages, the spleen, and portions of the liver, stomach, pancreas, prostate, and bladder, are now being successfully removed as well. Age in itself is no longer a contraindication to operation and an increasing number of resections in patients in their seventies and even eighties are being done. In the colon the number of resections, whether by ileocolectomy or colectomy, has increased markedly. In the right colon, resection and primary anastomosis have always constituted the usual procedure. Two stage resection with ileocolostomy at the first stage or resection by the exteriorization method has rarely been performed at this hospital even in the presence of obstruction. Before the introduction of the Miller-Abbott tube, decompression in cases of obstruction was usually accomplished by jejunostomy or ileostomy before or at the time of resection. Since 1938 when Whipple first demonstrated the value of the Miller-Abbott tube in the treatment of patients with right colon tumors, it has been introduced almost routinely in these patients before operation. Occasionally, in cases of obstruction, if it proved ineffective or failed to pass to the lower ileum, an ileostomy was done. In a few instances a cecostomy was performed before resection to relieve distention, and the stoma was later removed with the resected cecum. In the left colon, the staged exteriorization procedure has been used more often but has proved less satisfactory than resection and primary anastomosis and, since 1938, has been rapidly replaced by the latter procedure. In fact, in the last 5 years of this review it was employed in only 2 instances. Resection and primary anastomosis have been accompanied by fewer complications, a shorter period of hospitalization, and, in recent years, a low operative risk. When obstruction was present tube cecostomy has frequently been done, usually preceding resection. It has been, and still is, often used at the time of resection to protect the anastomosis against the danger of distention. Transverse colostomy has not been

From the Department of Surgery, College of Physicians and Surgeons, Columbia University, and the Surgical Service of the Presbyterian Hospital, New York.

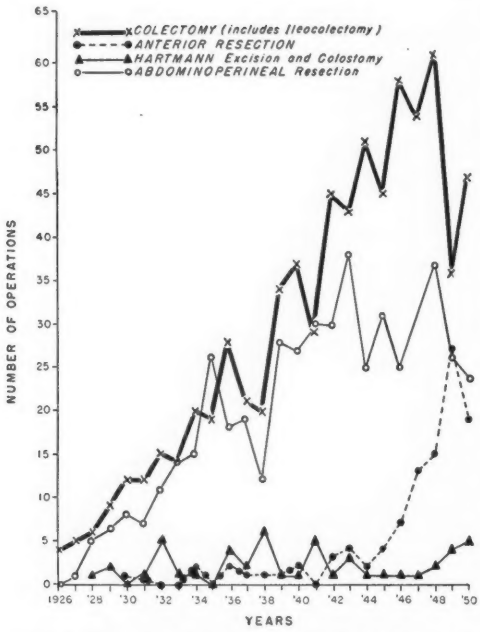
COLECTOMY (includes Ileocolectomy)
ANTERIOR RESECTION
HARTMANN Excision and Colostomy
ABDOMINOPERINEAL Resection
NUMBER OF OPERATIONS
YEARS
1926 '28 '30 '32 '34 '36 '38 '40 '42 '44 '46 '48 '50

Fig. 1. Incidence of operations for carcinoma of the colon. Abdominoperineal resection is included for comparison.

performed frequently. In recent years many tumors of the lower sigmoid and upper rectum which were formerly removed by abdominoperineal resection have been removed by anterior resection without sacrifice of the anal sphincter. The majority of these tumors lay above the pelvic peritoneum. The term, anterior resection, has been applied here to the removal of tumors of the upper rectum or lower sigmoid by resection and anastomosis, usually with mobilization of the upper rectum and lower sigmoid posteriorally and laterally, and always with excision of at least a part of the inferior mesenteric artery or its superior hemorrhoidal continuation and the accompanying lymph nodes. It does not include tumors of the sigmoid removed by simple wedge resection of the mesentery with excision of only the branches of these vessels. Recently greater efforts have been made to ligate the vessels supplying any involved segment of bowel at the highest possible point so as to remove the maximum number of lymph nodes and also to remove a wide segment of bowel and mesentery on each side of the tumor because of possible lateral spread along the lymphatics. Since 1949 high ligation of the inferior mesenteric artery, preferably at its origin at the aorta, has been done with increasing frequency in tumors of the sigmoid and descending colon. Simple wedge resection has been used chiefly for the poor risk patient. The Hartmann procedure with excision of the tumor, colostomy, and inversion of the distal stump has been employed occasionally when it was found inadvisable to complete the anastomosis in an anterior resection or to proceed with the perineal part of an abdominoperineal resection of a relatively high tumor because of the patient's condition. In the last 10 years aseptic closed types of anastomosis have been almost completely replaced by open anastomosis. The latter is simpler and permits more careful and accurate suturing. The danger of contamination and infection has been minimized by the use of the newer chemotherapeutic and antibiotic agents. The closed type of anastomosis has not been used in any case since 1948. In the right colon end-to-end suture of the ileum and transverse colon has recently tended to replace end-to-side suture. In the left colon end-to-end suture has always been customary.

In the treatment of carcinoma of the rectum, abdominoperineal resections have been performed with increasing frequency. Nearly all have been one stage procedures done according to the Miles technique. In the early cases, a few tumors were removed by a modified Kraske posterior resection but this procedure has not been used in the past 20 years. Prior to 1942, a two stage operation of the Coffey, Rankin, or Lahey type was performed in rare instances. Since 1942, however, nearly all operations have been one stage. Occasionally, in the presence of obstruction, a cecostomy has been done before resection. Recently a synchronous two team resection has been used in particularly feeble and depleted patients to shorten operating time. As previously mentioned, the number of abdominoperineal resections has decreased somewhat in the last 2 years, largely because of the recent popularity of anterior resection as an alternate

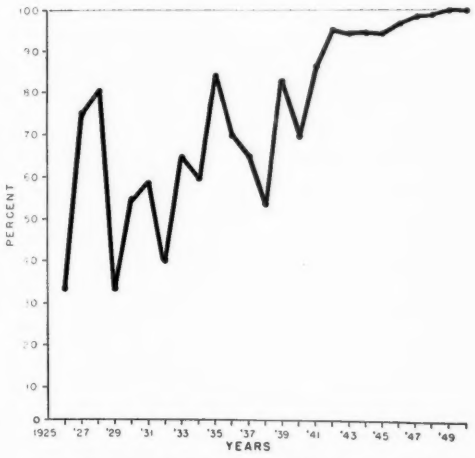

Fig. 2. Percentage of resections with primary anastomosis as opposed to those done with the exteriorization procedure in carcinoma of the colon.

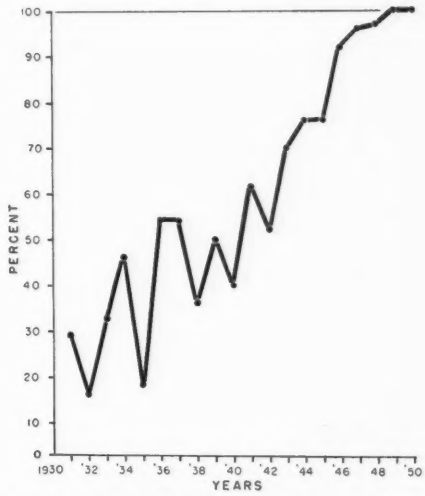

Fig. 3. Percentage of open anastomoses as opposed to closed anastomoses in resections for carcinoma of the colon.

procedure in borderline lesions. Pull-through procedures have been done in only a few cases. They appear to us to have only a limited usefulness in carcinoma of the rectum and have been accompanied by numerous complications. Perineal proctectomy has never been employed extensively. Its highest incidence was in 1930. It was used chiefly for low lying lesions in poor risk patients. Since 1944 it has not been employed in any instance because of the inadequate lymph node removal that it was found to afford. Recently there has been an increase in the number of local excision operations for carcinoma as a result of improved diagnosis and greater use of sigmoidoscopy. Most of these have been for small adenomatous polyps which were later found on microscopic section to show early carcinomatous changes. As in carcinoma of the sigmoid, ligation of the inferior mesenteric artery at its origin from the aorta has been done with increasing frequency since 1949 to permit wider removal of the lymph nodes along the upward route of spread in abdominoperineal resections. Palliative operations in general have decreased in frequency. Palliative resection has tended to replace other palliative measures, such as colostomy. If the tumor is high enough, anterior resection is especially suitable for this purpose.

From 1916 to 1950 inclusive there were 2,341 patients admitted to the Presbyterian Hospital with carcinoma of the large intestine, 1,315 with colon and 1,026 with rectal lesions. None of these patients had had previous curative treatment elsewhere. Fifty-six patients who had had such treatment were not included in this study. The ratio of carcinoma of the colon to carcinoma of the rectum was 1.3 to 1. In the colon series there were 656 men and 659 women, a nearly equal number, whereas in the rectum series there were 590 men and 436 women, a ratio of 1.4 to 1. The mean age for patients with cancer of the colon was 58.3 years, 59.5 for men and 57.1 for women. For patients with cancer of the rectum it was 56.7 years, 57.3 for men and 55.6 for women. The location of the tumors is shown in Table III. Only tumors from patients who had undergone operation and the site of which, therefore, could be verified more accurately were included.

From 1916 to 1945 inclusive, there were 1,667 patients admitted with carcinoma of the large intestine, 890 with cancer of the colon and 777 with cancer of the rectum. This

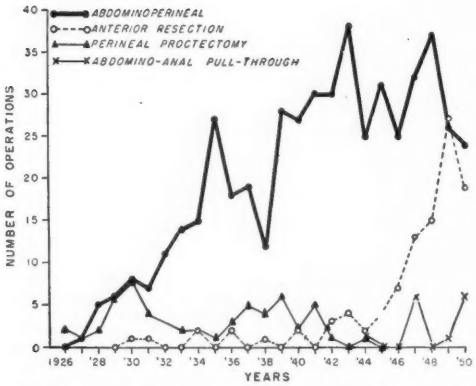

Fig. 4. Incidence of operations for carcinoma of the rectum. Anterior resection is included to show its effect on the incidence of abdominoperineal resection.

group was studied for 5 year survival results.

With improvements in anesthesia, surgical technique, bowel decompression, preoperative and postoperative patient care, and with the new chemotherapeutic and antibiotic agents, the resectability rate has risen considerably in recent years. As is usually done, the rate was calculated as the ratio of the cases in which the tumor was removed to the total operated on. Palliative resections and tumors removed by local excision were included. In both the colon and rectum the rate has shown a steady rise since 1916 to 92.1 and 83.3 per cent respectively for the last 5 year period. During the same interval, operative mortality in resected cases decreased from 31.3 and 40.9 per cent for the colon and rectum respectively to 5.3 and 6.7 per cent in the last 5 year period. A resectability rate that excludes palliative resections and palliative local excisions and is based on the ratio of all cases in which the tumor was removed to the total admitted to the hospital rather than to the total operated upon measures more accurately the effectiveness of the treatment given. This is shown in Table V.

TABLE I.—CANCER OF THE COLON AND RECTUM IN 2,341 CASES FROM 1916 TO 1950 INCLUSIVE

	Local excision	Curative resection	Palliative resec.	Other palliative operations	Total operations	No operations	Total primary admissions
Colon							
1916–1945 (Available for 5 year analysis)	10	521	40	242	813	77	890
1946–1950	16	304	55	32	407	18	425
Total	26	825	95	274	1,220	95	1,315
Rectum							
1916–1945 (Available for 5 year analysis)	14	440	17	227	698	79	777
1946–1950	37	133	25	39	234	15	249
Total	51	573	42	266	932	94	1,026

The 5 year follow-up results of all patients admitted to the Presbyterian Hospital for carcinoma of the colon and rectum from 1916 to 1945 inclusive are shown in Tables VI and VII. They have been compiled as far as possible according to standards adopted by the Cancer Commission of the League of Nations (14) in 1929. They include 890 primary colon and 777 primary rectal cases. They are designated as primary cases since none had received curative treatment elsewhere prior to admission. Five years after treatment 244 colon and 199 rectal patients were alive, a survival rate of 27.4 and 25.6 per cent respectively. In calculating these rates no deductions from the total number of primary cases were made. In 531 colon and 454 rectal cases of the original group, treatment could be given with a chance of cure. This represents a reduction to 60 and 58 per cent of the total number. Thus approximately 40 per cent could only be offered palliative treatment. The survival rates for this group were 46.0 per cent for the colon and 43.8 per cent for the rectal cases. The majority of patients on whom no operation was done had either too advanced disease or were too sick to be benefited by any surgery. About one-third refused operation. The difference between the 5 year survival and cure rates shows that 9 patients with cancer of the colon, representing 1 per cent of the original total number or 3.6 per cent of the 5 year survivals, were found alive with persistent cancer 5 years after operation. There were 11 such patients with cancer of the rectum, giving corresponding percentages of 1.5 and 5.5 per cent. If a longer follow-up period

had been maintained, the incidence of cancer persisting after 5 years would undoubtedly have been slightly higher. In a 10 year follow-up study, Colcock reported 22 patients with carcinoma of the colon who survived resection 5 years. Of these, 3 or 13.6 per cent died of malignant disease in the next 5 years. Of 49 patients with carcinoma of the rectum who survived resection 5 years, 8 or 16.3 per cent died of recurrence in the succeeding 5 years. Out of a group of 78 5 year survivors following abdominoperineal resection for carcinoma of the rectum, Coller (6) reported 29 or 37 per cent dying of cancer between the fifth and tenth years. As Colcock suggests, however, there is always the possibility that some of these patients may have been suffering from another undetected primary lesion arising in the colon and rectum. In our colon cases, microscopic proof of the diagnosis was obtained in 99.9 per cent of the resections, in 58 per cent of the palliative cases, and in 85 per cent of all cases. In the rectal cases microscopic proof was obtained in 99.9 per cent of the resections, 78 per cent of the palliative cases, and in 91 per cent of all the cases. In most of the cases without microscopic proof there was little doubt clinically as to the diagnosis. A follow-up of over 5 years or to the death of the patient if it occurred before that time was obtained in 98 per cent of all patients with colon lesions undergoing resection and in 99 per cent of those undergoing abdominoperineal resection.

There were 561 colon resections done from 1916 to 1945 inclusive. Forty of these were palliative. Of the 521 patients operated on with chance for cure, 45.5 per cent were alive at 5 years. In this group were 306 colectomies, 164 ileocolectomies, 21 anterior resections, and 30 anterior excisions with colostomy (Hartmann). Thirty of the 40 patients who had had palliative resections had obvious liver metastases at operation. Four patients had scattered peritoneal implants and the remaining 6 had extensive retroperitoneal spread. There were 379 abdominoperineal resections done from 1916 to 1945. Thirteen of these were palliative. Of the 366 patients operated on with chance for cure 46.4 per cent were alive at 5 years. Ten of the 13 patients having palliative resections were found to have obvious liver metastases at operation. The other 3 patients had extensive invasion of the peritoneum and retroperitoneal tissues. As palliative resections are being performed with increasing frequency it will be all the more necessary to present the curative resections separately for purposes of comparison. The decision as to which case should be called curative and which palliative is not always easy. Obviously, the more borderline cases that are put in the palliative group, the better the results of the curative resections will be. We have tried to classify as palliative only those cases in which definite unremovable cancer was known to have existed prior to operation or was found during it. The majority of the palliative cases were those with liver metastases. But there still remains a

TABLE II.—AGE INCIDENCE, 1916 TO 1950 INCLUSIVE

Age, years	Colon		Rectum	
	No.	Per cent	No.	Per cent
10–19	1	0.1	1	0.1
20–29	14	1.1	16	1.6
30–39	84	6.4	86	8.4
40–49	217	16.5	165	16.1
50–59	337	25.6	319	31.1
60–69	413	31.4	298	29.0
70–79	224	17.0	121	11.8
80–89	22	1.7	20	1.9
90–99	3	0.2	—	—
Total	1,315	100	1,026	100

TABLE III.—LOCATION OF TUMORS IN OPERATIVE CASES, 1916 TO 1950 INCLUSIVE

	No.		Per cent	
Cecum	110		5.1	
Ascending	134		6.3	
Hepatic flexure	43		2.0	
Proximal transverse	83		3.9	
Right colon		370		17.2
Distal transverse	106		4.9	
Splenic flexure	62		2.9	
Descending	105		4.9	
Sigmoid	577		26.7	
Left colon		850		39.5
Rectosigmoid and rectum		932		43.3
Total		2,152		100.0

TABLE IV.—RESECTABILITY, 1916 TO 1950 INCLUSIVE

Years	Total operations	Resectability	
		Resections	Per cent
Colon			
1916–1920	42	21	50.0
1921–1925	44	22	50.0
1926–1930	59	40	67.8
1931–1935	154	93	60.4
1936–1940	219	168	76.1
1941–1945	295	227	76.9
1946–1950	407	375	92.1
Rectum			
1916–1920	35	23	65.7
1921–1925	36	22	61.1
1926–1930	77	43	55.8
1931–1935	151	89	58.9
1936–1940	192	129	67.2
1941–1945	207	165	79.7
1946–1950	234	195	83.3

TABLE V.—RESECTABILITY WITH CHANCE OF CURE, 1916 TO 1950 INCLUSIVE

Years	Primary cases admitted No.	Resected with chance of cure	
		No.	Per cent
Colon			
1916–1920	51	21	41.2
1921–1925	48	21	43.8
1926–1930	75	40	53.3
1931–1935	167	91	54.5
1936–1940	231	154	66.7
1941–1945	318	204	64.2
1946–1950	425	320	75.2
Rectum			
1916–1920	40	23	57.5
1921–1925	39	22	56.4
1926–1930	89	43	48.3
1931–1935	164	84	51.2
1936–1940	214	125	58.4
1941–1945	231	157	68.0
1946–1950	249	170	68.3

certain number of cases about which the surgeon is in doubt. For example, nodules palpated in the liver at operation, especially single ones, less than 2 centimeters, in diameter, are not necessarily metastases and their presence should not necessarily put the case into the palliative category. In this series there were 13 patients with colon tumors and 9 with rectal lesions in whose liver nodules of this kind were seen or felt at operation, who were well 5 years or more later. Again, it may be difficult to decide at operation whether the fixation of a tumor to the wall of the pelvis is caused by inflammation or by local spread of the cancer and whether a resection under these conditions is curative or palliative. Again, the presence of enlarged periaortic lymph nodes may suggest that metastases are widespread and that the resection is palliative, whereas in reality the nodes are inflammatory and the resection is curative.

An analysis of the absolute 5 year survival rates for patients with colon and rectal cancer by 5 year periods from 1916 to 1945 showed a general rise over this 30 year period. This was largely a result of a corresponding increase in resectability and a fall in operative mortality. In the colon the rate rose from 5.9 per cent for the 1916 to 1920 period to 32.0 per cent for the 1936 to 1940 period. In 1941 to 1945, however, it dropped to 30.8 per cent. This decline is slight but represents a reversal of the previous upward trend. The rate for patients with rectal cancer rose similarly to a high point of 32.7 per cent for the 1936 to 1940 period and then dropped to 28.6 per cent for 1941 to 1945. As shown in Table V there was a slight increase between these two periods in the proportion of palliative to curative procedures in the colon which might explain the poorer results, but, in the rectum, the percentage of resections believed to be curative rose markedly between these two periods. The conclusion seems definite that in the rectum especially, treatment was less effective from 1941 to 1945 as compared to the previous 5 year period. In the results of curative colon and abdominoperineal resections a somewhat similar situation was found. The 5 year survival results of curative colon resection from 1916 to 1930 and for 5 year periods since then showed a continued slow rise from 37.0 per cent in the 1916 to 1930 period to 47.5 per cent for the last period.

TABLE VI.—CARCINOMA OF THE COLON IN ALL HOSPITAL ADMISSIONS, 1916 TO 1945 INCLUSIVE

Total cases admitted..... 907
Secondary cases, previous curative treatment elsewhere..... 17
Primary cases, no previous curative treatment elsewhere..... 890
Ward.....624 Private.....266

	No.	5 year survivals	5 year survivals without persistent cancer
Ileocolectomy	173	77	77
Colectomy	325	137	128
Anterior resection	24	12	12
Excision and colostomy (Hartmann)	39	11	11
Local excision	10	7	7
Exploratory celiotomy	57	—	—
Colostomy	58	—	—
Cecostomy	43	—	—
Ileostomy	4	—	—
Appendicostomy	3	—	—
Ileocolostomy	43	—	—
Colocolostomy	27	—	—
Incision and drainage of abscess	7	—	—
No operation	77	—	—
	890	244	235

Absolute 5 year survival rate = $\frac{244}{890}$ = 27.4 per cent

Absolute 5 year clinical cure rate = $\frac{235}{890}$ = 26.4 per cent

TABLE VII.—CARCINOMA OF THE RECTUM IN ALL HOSPITAL ADMISSIONS, 1916 TO 1945 INCLUSIVE

Total cases admitted..... 804
Secondary cases, previous curative treatment elsewhere..... 27
Primary cases, no previous curative treatment elsewhere..... 777
Ward.....557 Private.....220

	No.	5 year survivals	5 year survivals without persistent cancer
Abdominoperineal resection	379	171	161
Perineal proctectomy	57	16	15
Sacral proctectomy (modified Kraske)	20	4	4
Abdominoanal pull-through	1	—	—
Local excision	14	8	8
Exploratory celiotomy	37	—	—
Colostomy	171	—	—
Cecostomy	7	—	—
Implantation of radium	12	—	—
No operation	79	—	—
	777	199	188

Absolute 5 year survival rate = $\frac{199}{777}$ = 25.6 per cent

Absolute 5 year clinical cure rate = $\frac{188}{777}$ = 24.2 per cent

When the results were calculated just for the operative survivors, however, eliminating the effect of the declining operative mortality, a sharp drop rather than a rise was found for the 1941 to 1945 period as compared to the preceding periods. The 5 year survival results of curative abdominoperineal resection were very similar. There was also a drop in the survival rate for the 1941 to 1945 period, especially pronounced when only operative survivors were studied. This was even more striking than in the colon results. It would appear that results in treating the cancer itself by curative colon or abdominoperineal resection have improved very little, and in the last 5 year period have even worsened. It is possible, of course, that we have been attempting curative resection on advanced tumors which in reality were not curable by surgery. We should not be deterred, however, from continuing to do radical resections on tumors whose curability is undetermined. The poorer absolute 5 year results, however, for the 1941 to 1945 period, especially in the rectal cases, remain unexplained. A possible explanation may be that from 1930 to 1940, 45 per cent of the abdominoperineal resections were done by one surgeon, the late Dr. Charles Janssen whose judgment and skill in handling these cases were outstanding. After his retirement in 1940, these operations were done by a much larger number of surgeons with less experience in this field. This was true to a lesser extent in the surgery of colon tumors during that period. It is in advanced tumors of the rectum, however, that accurate dissection wide of the tumor is particularly difficult and yet essential if cure is to be obtained. Spear and Brainard also found little change between their earlier and more recent 5 year results after eliminating operative deaths. Coller (6) reported a 28.4 per cent 5 year survival rate in 1,064 patients with cancer of the rectum treated from 1935 to 1945. His series included anterior resections, however, and is therefore not strictly comparable to this series. It is

TABLE VIII.—CURATIVE COLON AND ABDOMINOPERINEAL RESECTION 1916 to 1945 INCLUSIVE

	Colon resections	Abdominoperineal resections
Operative deaths	92	62
Untraced for full 5 years	12	4
Died of intercurrent disease or unknown cause before 5 years	35	27
Died of cancer before 5 years	145	103
Alive with cancer persisting 5 years after operation	9	11
Alive without cancer 5 years after operation	228	159
Total curative resections	521	366
Relative 5 year survival rate	$\frac{237}{521}$ = 45.5 per cent	$\frac{170}{366}$ = 46.4 per cent
Relative 5 year clinical cure rate	$\frac{228}{521}$ = 43.8 per cent	$\frac{159}{366}$ = 43.4 per cent

too early as yet to evaluate the effect on the survival rate of recent more radical operations on the lymphatic extensions of colon and rectal cancer as proposed by McKittrick (15), Dunphy (10, 11), Deddish (8, 9), Bacon and Sauer (2, 19), State (21), Ault, Castro, and Smith (1), and Grinnell (12, 13).

A comparison of the results of curative resections in the various segments of the colon showed them to be very similar with the exception of the hepatic flexure. There was little difference between the results obtained in the right and left colon. This finding is at variance with that generally reported in the literature, which has shown a higher 5 year survival for patients with right colon lesions. This fact is usually attributed to a more radical removal of bowel and mesentery in these tumors. The low 5 year survival rate for patients with carcinoma of the hepatic flexure came as a surprise. This is a small group of only 14 cases, however. Apparently, because of their location, these tumors were

TABLE IX.—ABSOLUTE SURVIVAL RATES, 1916 TO 1945 INCLUSIVE

Years	Primary cases admitted No.	5 years survivals No.	5 years survival rate per cent
Colon			
1916–1920	51	3	5.9
1921–1925	48	11	22.9
1926–1930	75	16	21.3
1931–1935	167	42	25.2
1936–1940	231	74	32.0
1941–1945	318	98	30.8
	890	244	
Rectum			
1916–1920	40	7	17.5
1921–1925	39	7	17.9
1926–1930	89	11	12.4
1931–1935	164	38	23.2
1936–1940	214	70	32.7
1941–1945	231	66	28.6
	777	199	

TABLE X.—RESULTS OF CURATIVE COLON AND ABDOMINOPERINEAL RESECTION, 1916 TO 1945 INCLUSIVE

Years	No.	Operative deaths	Mortality per cent	5 year survivals	
				No.	Per cent
Colon resections					
1916–1930	81	24	29.6	30	37.0
1931–1935	90	17	18.9	41	45.6
1936–1940	150	33	22.0	71	47.3
1941–1945	200	18	9.0	95	47.5
1946–1950	304	19	6.3	—	—
Abdominoperineal resections					
1916–1930	43	17	39.5	13	30.2
1931–1935	70	17	24.3	34	48.6
1936–1940	106	17	16.0	61	57.5
1941–1945	147	11	7.5	62	42.5
1946–1950	123	8	6.5	—	—

TABLE XI.—RESULTS OF OPERATIVE SURVIVALS, CURATIVE COLON AND ABDOMINOPERINEAL RESECTION

Years	Operative survivals	5 year survivals	
		Cases	Per cent
Colon resections			
1916–1930	57	30	52.6
1931–1935	73	41	56.2
1936–1940	117	71	60.7
1941–1945	182	95	52.2
Abdominoperineal resections			
1916–1930	26	13	50.0
1931–1935	53	34	64.2
1936–1940	89	61	68.5
1941–1945	136	62	45.6

TABLE XII.—CURATIVE COLON RESECTIONS, 1916 TO 1945 INCLUSIVE

	Operative cases	Operative survivals	Operative mortality Per cent	No.	5 year survivals	
					Per cent of operative cases	Per cent of operative survivals
Cecum	51	42	17.6	25	49.0	59.5
Ascending	70	60	14.3	33	47.1	55.5
Hepatic flexure	14	12	14.3	3	21.4	25.0
Proximal flexure	51	42	17.6	24	47.1	57.1
Right colon	186	156	16.1	85	45.7	54.5
Distal transverse	53	44	17.0	23	43.4	52.3
Splenic flexure	27	24	11.1	14	51.9	58.3
Descending	52	43	17.3	26	50.0	60.5
Sigmoid	203	162	20.2	89	43.8	54.9
Left colon	335	273	18.5	152	45.4	55.7
Right and left colon	521	429	17.7	237	45.5	55.2

found to invade the liver and duodenal region early. Only 3 patients were alive 5 years after operation. Five patients died of cancer. Three of the 5 showed spread to the duodenum or to the tissues close to it, and the other 2 patients developed liver metastases. In order to obtain a larger group if possible, the pathological and operative reports and barium enema roentgenograms of tumors lying in the ascending and proximal transverse colon were reviewed. Eighteen additional patients were found whose tumors lay in the ascending or distal limb of the hepatic flexure impinging on the flexure itself. Of these, 10 died of cancer following resection. Two of these patients showed early invasion of the duodenum at operation and later developed local recurrence there. One showed invasion of the hepatocolic ligament at operation and later developed liver involvement. Three others died of liver metastases. In the remaining cases the location of the recurrence was not accurately known. If these 18 cases are added to the original 14, the 5 year survival rate for this group becomes 34 per cent or 36.7 per cent for the operative survivors. These percentages are well below those for other segments of bowel. Eighteen patients with hepatic flexure tumors received only palliative surgery. Of these, 10 were found to have liver metastases at operation. In 2 the liver involvement was by direct spread from the tumor. Direct invasion of the duodenal and adjacent tissues

TABLE XIII.—RESECTABILITY RATE 1916 TO 1950 INCLUSIVE

	Total operations	Resections	
		No.	Per cent
Cecum	110	83	75.5
Ascending	134	110	82.1
Hepatic flexure	43	21	48.8
Proximal transverse	83	71	85.5
Right colon	370	285	77.0
Distal transverse	106	87	82.1
Splenic flexure	62	44	71.0
Descending	105	83	79.0
Sigmoid	577	447	77.4
Left colon	850	661	77.7

TABLE XIV.—OPERATIVE SURVIVORS OF CURATIVE RESECTIONS OF COLON AND RECTUM WITHOUT AND WITH LYMPH NODE METASTASES, 1936 TO 1945 INCLUSIVE

	Total No.	5 year survivals	
		No.	Per cent
Without node metastases			
Colon	184	125	67.9
Rectum (abdominoperineal and perineal proctectomy)	141	95	67.4
With node metastases			
Colon	117	43	36.7
Rectum (abdominoperineal and perineal proctectomy)	104	36	34.6

TABLE XV.—RESULTS BY AGE DECADES, CURATIVE COLON AND ABDOMINOPERINEAL RESECTION, 1916 TO 1945 INCLUSIVE

Age range, years	5 year survivals and those dead of cancer under 5 years	5 year survivals	
		No.	Per cent
Colon			
10–19	1	—	—
20–29	3	2	66.6
30–39	36	22	61.1
40–49	67	40	59.7
50–59	105	67	63.8
60–69	116	72	62.1
70–79	51	31	60.8
80–89	2	1	50.0
90–99	1	—	—
Rectum			
10–19	—	—	—
20–29	6	4	66.6
30–39	32	22	68.7
40–49	56	33	58.9
50–59	88	59	67.0
60–69	69	42	60.8
70–79	23	8	34.8
80–89	1	—	—
90–99	—	—	—

TABLE XVI.—INCIDENCE OF LYMPH NODE METASTASIS BY AGE IN RESECTIONS OF COLON AND RECTUM, 1916 TO 1950 INCLUSIVE

Age range, years	Total No.	Node metastases present	
		No.	Per cent
Colon			
10–19	1	—	—
20–29	7	3	42.9
30–39	64	28	43.8
40–49	152	62	40.8
50–59	246	92	37.4
60–69	298	112	37.6
70–79	138	54	39.1
80–89	12	4	33.3
90–99	2	2	—
Rectum			
10–19	1	1	—
20–29	9	6	66.7
30–39	48	27	56.7
40–49	97	44	45.4
50–59	189	91	48.1
60–69	185	75	40.5
70–79	65	25	38.5
80–89	2	1	50.0
90–99	—	—	—

was found in 5 patients. The poorer prognosis of tumors of the hepatic flexure was further shown by their low resectability rate of only 48.8 per cent as compared to 77 per cent for the entire colon.

The importance of lymphatic metastasis in the prognosis of these tumors is, of course, well known. The results were compared in patients with and without lymph node metastases in their resected specimens who survived curative colon resection, curative abdominoperineal resection, and perineal proctectomy from 1936 to 1945. In the colon group, the survival rate was 67.9 per cent for those without metastases and 36.7 per cent for those with metastases. The results in the rectum group were very similar.

A comparison was made of the 5 year survival results following colon resection and abdominoperineal resection of the rectum in the different decades of life. It has been asserted that cancer of the colon and rectum tends to grow more rapidly and metastasize earlier in young people. Buser, Kirsner, and Palmer, however, found no correlation between age and survival in large bowel tumors. For purposes of comparison in this study only 5 year survivors and those who died of cancer under 5 years were included. It seemed important to exclude operative deaths, and deaths from intercurrent disease, since they are more frequent in older patients. In the colon group there was little difference between the various decades and no evidence that cancer of the colon is more fatal in the young. In the rectum group, the incidence of survival was similar in each decade except for that of patients in the seventies. Here it was somewhat poorer but the group was too small a one on which to base conclusions. The poorer results can perhaps be attributed to less radical and less meticulous surgery in these debilitated patients who were less able to withstand long operations. Rankin and Comfort found

that the incidence of lymph node metastasis in cancer of the rectum was higher and the results of surgery poorer in patients under 30 years of age. We had too few patients under 30 to warrant any significant conclusions. The incidence of node metastasis in both colon and rectal specimens removed in the different age groups was slightly higher in patients under 40 years of age but the number of younger patients is too small to make the difference very significant.

The results of 53 curative colostomy and perineal protectomy operations for carcinoma of the rectum from 1916 to 1945 inclusive showed a 5 year survival rate of 32.1 per cent. This was approximately 13 per cent lower than that following abdominoperineal resection over a similar period. The operation was used mainly for low lying carcinomas in older poor risk patients and was usually done in two stages. Four strictly palliative cases were omitted. The overall operative mortality was 9.4 per cent as compared to 16.9 per cent for abdominoperineal resection. As already mentioned, the operation has not been employed since 1944 because it does not permit adequate removal of the mesenteric lymph nodes. This is apparently the chief reason for its lower 5 year cure rate as compared to abdominoperineal resection.

The ratio of palliative to curative operations has decreased markedly over the years. Palliative resection has increased, however, and has tended to replace colostomy and sidetracking operations. Removal of the primary focus appears to afford the patient greater comfort. According to Daland, Welch, and Nathanson colostomy does not prolong life beyond the average life expectancy of patients with untreated cancer, which is an average of 17 months from the onset of symptoms. Modlin and Walker reported no significant difference in the average length of survival of untreated patients and those receiving colostomy or palliative resection. They believed, however, that the majority of palliative resections gave worthwhile relief to the patient. From 1934 to 1948 the average period of survival in 48 patients after palliative colon resection was 12 months, and in 19 patients after palliative abdominoperineal resection it was 17 months. The average survival after palliative colon and rectal operations other than resection in 92 and 102 patients was 5½ months and 8 months, respectively, but these patients were usually in a more advanced stage of the disease. Patients who died in the hospital after operation or from intercurrent disease after operation were not included. The longest survival after palliative resection of the colon was 53 months and of the rectum, 57 months. The average survival after palliative resection was 5 months longer in patients with rectal cancer than in those with cancer of the colon. As might be expected, it apparently takes longer for pelvic tumors to reach the more vital areas. The operative mortality in the palliative resections of the colon was 10 per cent and in the other palliative operations 28 per cent. There was no mortality in the small group of palliative resections of the rectum. In the other palliative operations the mortality was 15 per cent.

SUMMARY AND CONCLUSIONS

1. The results of treatment of 890 patients with carcinoma of the colon and 777 patients with carcinoma of the rectum admitted to the Presbyterian Hospital, New York, from 1916 to 1945 inclusive have been presented. These were patients who had not had previous curative treatment.

2. The resectability rate for colon tumors rose from 50 per cent for the 1916 to 1920 period to 92.1 per cent for the 1945 to 1950 period and the operative mortality fell from 31.3 to 5.3 per cent for these same periods. For rectal tumors the resectability rate rose from 65.7 per cent to 83.3 per cent and the operative mortality fell from 40.9 to 6.7 per cent.

3. The absolute 5 year survival rate for patients with carcinoma of the colon admitted to the hospital from 1916 to 1945 inclusive was 27.4 per cent. For patients with carcinoma of the rectum the absolute 5 year survival rate was 25.6 per cent. During the 1941 to 1945 period there was a decrease in the survival rates of both the colon and rectal groups.

4. The relative 5 year survival rates for patients undergoing curative colon and abdominoperineal resection from 1916 to 1945

was 45.5 and 46.4 per cent respectively. In both colon and rectal groups during the 1941 to 1945 period there was a decrease in the survival rates of those patients who survived operation.

5. The 5 year results following curative colon resection were very similar for the right and left colon. The poorest results were in tumors of the hepatic flexure because of early spread to the liver and duodenal area. The resectability rate of these tumors was also much lower than that for other segments of the colon.

6. The 5 year survival rate for patients who were treated by curative colon resection from 1936 to 1945 and survived operation was 67.9 per cent for those without node metastasis in the resected specimens and 36.7 per cent for those with node metastasis. The rate for patients treated by curative abdominoperineal and perineal proctectomy was 67.4 per cent for those without metastasis and 34.6 per cent for those with metastasis.

7. There was no evidence found in a study of the 5 year results that the chances of survival following curative colon resection or curative abdominoperineal resection were less in the younger age group.

8. The 5 year survival rate for 53 patients with carcinoma of the rectum treated by colostomy and perineal proctectomy from 1916 to 1945 was 32.1 per cent. The rate was approximately 13 per cent lower than that following abdominoperineal resection over a similar period.

9. Although the absolute 5 year survival rate of patients with large bowel cancers has risen in the past 30 years, chiefly because of the rise in resectability and the fall in operative mortality, there is little evidence in the bare percentages themselves of any recent improvement in our surgical attack on the cancer itself. The actual drop in the survival rate in the last 5 year period, especially in rectal cancers, suggests that our treatment has been less effective than previously. The actual decline in the survival rate of operative survivors in 1941 to 1945 following curative colon and abdominoperineal resection may be caused in part by attempting curative resections on advanced tumors which in reality were not curable by surgery. We should not be deterred, however, from continuing to do radical resections on tumors whose curability is undetermined.

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BRACHIAL AND ANTEBRACHIAL ARTERIAL PATTERNS

A Study of 750 Extremities

LAWRENCE J. McCORMACK, M.D., EARL W. CAULDWELL, M.D., and
BARRY J. ANSON, Ph.D. (Med. Sc.), Chicago, Illinois

STRIKING variations in the origin and course of the principal arteries of the upper extremities have long received the attention of anatomists and surgeons. Many of the studies which have contributed to our knowledge of these vascular structures have, however, failed to treat the subject in sufficient descriptive detail, with a resulting tendency to oversimplification. Furthermore, discrepancies have been introduced through the use of neologisms to suit individual convenience. Accurate knowledge of the relationships and course of these major arterial conduits, and particularly of their variational patterns, is of considerable practical importance in the conduct of reparative surgery in the arm, forearm, and hand. It is, therefore, the purpose of this study to review briefly the existing data, and to present the anatomy of major arterial variations encountered in an extensive series of dissected specimens.

Tiedeman (1831) first systematically described the variations in the arterial pattern of the upper extremities. His bibliography gives 38 references to observations made prior to 1817, the earliest of which is that by Laurentius (1600). Quain's series (1844) of over 400 extremities was, it is believed, the first to provide data sufficient for useful statistical evaluation, and the only large series appearing in the English language up to that time.

Many articles, concerned chiefly with single examples of anomalies, subsequently appeared in the literature. Few authors attempted to review these data. Among the investigators who presented such a correlation should be mentioned Henle (1868), who provided an analysis of the large European series studied prior to his time, and Poynter (1920) who summarized all series which had appeared up to 1920, adding 250 specimens of his own, to provide a total of several thousand.

Contribution No. 589 from the Anatomical Laboratory of Northwestern University Medical School.

MATERIAL AND METHODS

Routine dissecting-room material was employed for the present study. The site of origin of each "anomalous" artery was recorded and measured with reference to the intercondylar line of the humerus, which served not only as a fixed point for all measurements, but also represented the proximal border of the antecubital fossa, above which bifurcation of the brachial artery was considered to represent a variational pattern.

The arterial variations were grouped in three categories, under which were placed suitable subdivisions both as to level of origin and to variations in distribution (Table IV). Major types were figured, in order to demonstrate the striking differences encountered (Figs. 1 to 4); additionally, certain of the graded variations were recorded schematically (Fig. 5).

The total series examined comprised 750 consecutive upper extremities from 386 adult cadavers; in 22 cadavers only one of the limbs was available for study. In this collection, 555 extremities were from white and 161 were from negro subjects, with 34 cases unrecorded as to race. Female cadavers occurred infrequently.

OBSERVATIONS

Statistical results. Departures from the anatomic norm, in respect to origin and course of the arteries, occurred in 139 of 750 extremities (18.53 per cent). Considered on the basis of the 364 (of 386) cadavers with both upper extremities represented, major arterial variations occurred in 112 (30.77 per cent). Bilateral occurrence was recorded in 23 cadavers

(6.32 per cent), while the remaining 89 (24.45 per cent) revealed variants unilaterally. In this series, approximately 1 in 3 bodies possessed an important deviation from the "normal" arterial pattern, usually occurring in 1 of the pair of arms, less commonly in both.

Earlier authors presented rather divergent reports on incidence, but in several cases the combined result was similar. Whereas in the current study, major variations were found in 18.53 per cent of 750 specimens, Quain encountered anomalies in 19.5 per cent of 481 extremities. Gruber (1848) in 8.6 per cent of 1,200, Muller (1903) in 14 per cent of 100, and Poynter in 20 per cent of 250 limbs.

There are several features affecting the modes of origin of the aberrant vessels in the present series which are of special statistical interest. Whereas variations occurred more frequently on the right side (76 right, 63 left) in a ratio of 1.2:1, comparison of those arising from the axillary artery with those of brachial artery origin revealed an interesting disparity: the variant vessels arising from the axillary artery were encountered chiefly on the left side in a ratio of 3:1 (18 left, 6 right), while those from the brachial artery were found predominantly on the right side in a ratio of 1.5:1 (65 right, 43 left).

These patterns of variation (Table I) tend to fall into 3 great groups,[1] with a single case in a fourth: first, those in which variations of the radial artery (affecting origin or course) constituted the major anatomic feature (81.3 per cent of all variations encountered); second, specimens in which occur variations of comparable order in the ulnar artery (12.22 per cent); third, instances in which variations of generally similar nature occurred in the brachial arterial pattern (5.75 per cent); fourth, a single case characterized by the presence of an accessory brachial artery (0.7 per cent). The relatively infrequent cases of unusual anastomosis, in or near the antecubital fossa, between the aberrant and adjacent channels, have been relegated to subgroups under the major types.

Superficial brachial artery[2]. Complete separation of radial and ulnar arteries, high above the intercondylar line of the humerus, was one of the more striking variations encountered in the present series. The main trunk arose from the axillary artery (Fig. 2a) in 1 instance, and from the brachial artery in 7 (Fig. 2b). On the basis of total specimens, 5 right and 3 left extremities made up an incidence of 1.07 per cent, or 5.75 per cent of the total number of variations (Table I). Gruber reported 5 cases of superficial brachial artery in 1,200 arms; Quain, 1 in 506; and Muller, 1 in 100 specimens.

The superficial brachial artery which took origin from the anterolateral aspect of the axillary arose 4 centimeters proximal to the junction of axillary and brachial arteries, and coursed between the contributions of the lateral and medial cords of the brachial plexus to the median nerve. The 7 specimens in

[1]De Vriese (1902) studied 8 human embryos ranging from 10 to 27 millimeters in length. In the earlier specimens the arteries of the forearm were intimately associated with the developing nerve bundles which supply the forearm musculature. In the 16 mm. embryo the artery accompanying the ulnar nerve received an anastomotic branch from the primitive axial stem. In the 18 mm. stage the superficial radial artery received a similar branch from the axial artery. The superficial radial artery had been previously formed at the 10.5 mm. stage by a division of the primitive vessel accompanying the radial nerve. These two anastomoses represented the levels of origin of the radial and ulnar arteries in the forearm. The more primitive stages were represented by smaller arteries; e.g., the *A. nervi radialis radialis* became the *A. profunda*, and the *A. interossei dorsalis* and the proximal portion of the *A. radialis superficialis* became the *A. radialis recurrentis*.

Muller (1903) was in general agreement with De Vriese, except concerning the fate of those vessels which lay anterior and posterior to the developing nerve mass, namely, the superficial radial artery and the primitive axial artery. In his 11 mm. specimen there were found 3 chief anastomoses between these two arteries. Muller laid great stress on the significance of these anastomoses, and, using them as a basis, he constructed a series of diagrams to explain the many variations.

More recently, Senior (1926) stated that embryos of 21 mm. possessed a vessel arising from the axillary artery which coursed anterior to the median nerve. It received an anastomosis from the primitive axial artery in the region of that vessel's termination in the ulnar, and then continued into the forearm as the radial artery. In the 23 mm. embryo the portion of the superficial vessel proximal to the anastomosis had for the most part disappeared. However, Senior (1943) stated that, in his opinion, it was impossible to work out the developmental anatomy of arm arteries to explain definitive variations of origin as he had previously done for the vessels of the lower limb.

[2]An attempt was made in describing these vessels to avoid the use of controversial or confusing terminology. The use of the term *A. brachialis superficialis* was retained because of its descriptive accuracy; this vessel lies superficial to the median nerve in an abnormal site and forms a common stem of origin for the radial and ulnar arteries. No unusual names were retained for radial arterial variations, since the course of the radial artery through the forearm was not changed by the anomalous origin of the vessel. Muller's classification, which divided radial variations into *A. radialis superior*, *A. radialis media*, and *A. radialis inferior*, on the basis of his embryologic findings, may here be regarded as superfluous, because the terms are not serviceable in a consideration of surgically important anatomical features. However, since a "normal" ulnar artery lies deep to the antebrachial musculature, it was considered desirable to retain the term *A. ulnaris superficialis* for a vessel which coursed through the forearm upon, rather than under, the flexor-pronator muscles.

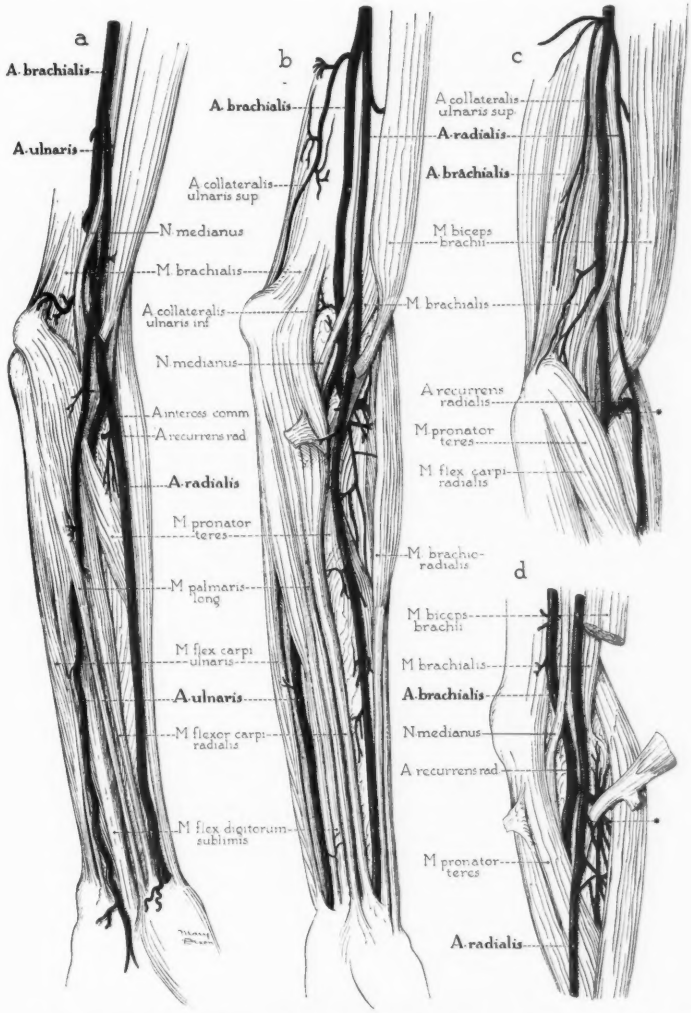

Fig. 1. Examples of variation in the level of division of the brachial artery and in the course and relations of the radial and ulnar branches; arranged in the order of progressively higher division. In addition to variation in the point of origin, from the main stem, of the radial and ulnar divisions, the following departures from the anatomic norm are recorded: in a, course of the ulnar artery superficial to 3 of the 4 muscles which constitute the first layer of the flexor-pronator set; in c, the occurrence of a superficial radial artery, which, while slight in caliber in its brachial portion, continues as a large vessel distal to the point of communication (at *) in the cubital fossa, with the brachial artery; in d, the occurrence of a communication (at *), distal to the cubital fossa, between a large radial artery and the volar interosseous artery.

which the vessel arose from the anteromedial surface of the brachial artery passed medially to the median nerve.

After taking origin, the superficial brachial artery typically followed a course along the medial border of the biceps muscle, and

TABLE I.—POINTS OF ORIGIN AND OF BIFURCATION OF SUPERFICIAL BRACHIAL ARTERY IN RELATION TO INTERCONDYLAR LINE

Distance of origin above intercondylar line in cm.	Length of superficial brachial in cm.	Point of bifurcation in relation to intercondylar line in cm.
Axillary artery 26	28	2.0 below
Brachial artery 21	17	4.0 above
17	16.5	0.5 above
16.5	16	0.5 above
15.5	16.5	1.0 below
12.5	17	4.5 below
12	14	1.5 below
10.5	10	4.5 below

supplied the latter with numerous muscular branches. The median nerve attained a position posterior to the aberrant vessel, and at the same time lay anterior to the deep brachial artery. In the distal part of the arm, the median nerve passed ulnarward and entered the forearm slightly internal to the deep brachial artery, which terminated as the definitive interosseous arteries. There was also a tendency for the superficial brachial artery to attain a slightly more lateral position with reference to the deep brachial in the distal portion of the arm.

Upon reaching its point of bifurcation, either above or below the intercondylar line (Table I), the superficial brachial artery split into radial and ulnar divisions (Fig. 2a and b). The relationships established by the radial division were generally constant. Upon emergence from the superficial brachial trunk, it coursed rather abruptly lateralward to lie along the medial border of the brachioradialis muscle, its regular anatomic position. The ulnar division, however, with a single exception, remained entirely superficial to the ventral musculature and descended in the forearm immediately beneath the antebrachial fascia. The ulnar branch continued in an arciform manner medialward over the proximal portions of the pronator teres, flexor carpi radialis, and flexor sublimis muscles, to gain a position in the distal one half of the forearm along the lateral border of the flexor carpi ulnaris muscle. At the junction of the middle and distal thirds of the forearm, the usual relationship to the lateral aspect of the ulnar nerve was established, and the artery, in continuing its course, entered the hand beneath the volar carpal ligament in the channel beneath the hook of the hamate and the pisiform bone. In a single exceptional case, the ulnar artery coursed in the same general manner, but passed beneath the proximal third of the palmaris longus muscle.

TABLE II.—BRACHIAL LEVEL OF ORIGIN OF RADIAL ARTERIES DISTANCE ABOVE INTERCONDYLAR LINE

Distance, cm.	Specimens, No.
Group I—No anastomosis	
20 and over	8
15–19.9	33
10–14.9	25
5– 9.9	5
0– 4.9	4
	75
Group II—Anastomosis anterior to biceps brachii tendon	
20 and over	1
15–19.9	4
10–14.9	6
	11
Group III—Anastomosis posterior to tendon	
15–19.9	2
Group IV—Anastomosis with median artery	
15–19.9	1

Radial artery. Instances of origin of the radial artery proximal to the intercondylar line formed by far the largest group of gross variations (Table II). This pattern was observed in 107 extremities, and represented an occurrence in 14.27 per cent of all specimens studied and 77 per cent of the variations (Fig. 4b). Of this group, 16 (2.13 per cent of total, 11.5 per cent of variations) arose from the axillary artery (14 on the left side, 2 on the right), whereas 91 (12.14 per cent of total, 65.5 per cent of variations) arose from some part of the brachial artery (54 right, 37 left).

In the group which arose from the axillary artery (16), 10 of the radial arteries emerged between the thoracoacromial and subscapular branches, 7 between the subscapular and an independent (usually anterior) humeral circumflex, and 1 directly opposite the posterior humeral circumflex artery. All of these originated within 6 centimeters of the brachioaxillary junction (Fig. 2c and d).

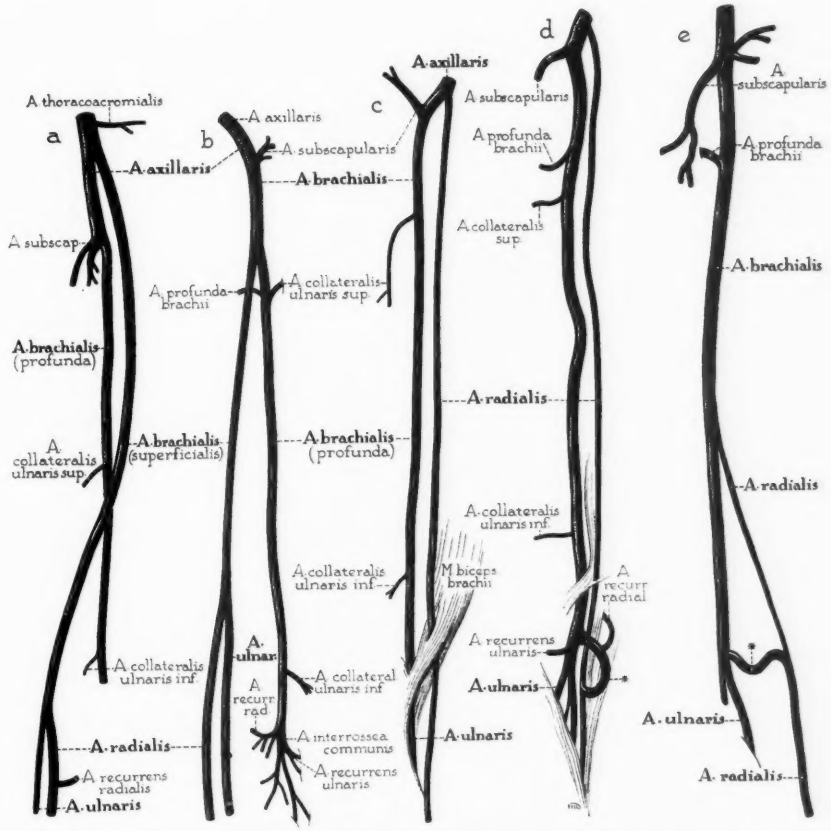

Fig. 2. Variations in the brachial arterial pattern, examples continued. Showing selected instances of high branching of the main vessel and of communication between axially coursing stems at the level of the cubital fossa. The treatment is schematic in the omission of nonessential musculature and of arterial rami to individual muscles. In addition to proximal brachial or axillary source of the major stems, the following features are noteworthy: in a and b, the occurrence of a paired brachial artery; in c, the passage of a superficial radial artery and an ulnar artery through the substance of the biceps brachii muscle; in d and e, the presence of a large anastomotic connection (at *) between the radial and ulnar arteries in the cubital fossa.

It is serviceable to subdivide the specimens further, this time into four groups, on the basis of type of anastomotic connection and without reference to the point of origin: group I (82 specimens), those radial arteries which made no significant gross anastomosis with other major vessels in their course through the arm and forearm (Figs. 1b, 2c); group II (14 specimens), in which an anastomosis was established with the deep or "regular" brachial artery in the antecubital region, the communicating vessel in these cases passing anterior to the biceps tendon (Figs. 1c, 2d); group III (5 specimens), all of them left extremities, in which a long, slender anastomosis with the brachial artery passed posterior to the biceps tendon (Fig. 1d); and group IV (1 specimen), in which an anastomosis with the median artery occurred in the forearm (compare with Fig. 1d).

The radial arteries which took origin from the brachial showed a marked tendency to

TABLE III.—ORIGIN OF ULNAR ARTERY FROM BRACHIAL DISTANCE PROXIMAL TO INTERCONDYLAR LINE

Distance, cm.	Specimens, No.
20.0 and over	1
15.0–19.9	3
10.0–14.9	3
5.0– 9.9	0
0.0– 4.9	1

arise in the proximal portion of the arm, rather close to those from the axillary artery (Table II).

In the origin and proximal course of these arteries, two important relationships should be noted: all of the radial arteries which arose from the axillary artery, and 4 of those derived from the proximal portion of the brachial artery, took origin from the anterior aspect of the parent vessel, and immediately passed between the elements of the lateral and medial cords of the brachial plexus which formed the median nerve; in the remaining specimens, the arteries arose from the anteromedial and medial surfaces of the brachial artery.

The relationships established by the aberrant radial artery in the arm showed considerable consistency; most important of the related structures were the median nerve and the biceps brachii muscle. Those vessels which passed through the forming elements of the median nerve lay anterior, but very close to the nerve, throughout the arm. Those vessels which arose after fusion of the elements of the median nerve passed medially and then anterior to the nerve (Fig. 1b and c). In all cases it was at this initial site of close relationship to the brachial artery that the median nerve departed from its slightly lateral position to become insinuated between the two arterial trunks for a distance of 6 to 8 centimeters. The radial artery then continued with medial inclination to enter the forearm on the inner aspect of the brachial artery. The second constant relationship maintained by the aberrant radial artery was that established with the medial border of the biceps muscle, a relationship maintained until the vessel passed medial to the biceps tendon to enter the forearm (Fig. 1b).

In the forearm, the radial artery soon coursed slightly lateralward to occupy the anatomic position of the "normal" vessel, along the medial border of the brachioradialis muscle and superficial to the pronator teres. Occasionally, in the distal portion of the forearm, a volar contribution was given to the palmar supply. In all but 1 specimen, the vessel passed beneath the dorsal tendons of the thumb just distal to the styloid process of the radius, to enter the deeper aspect of the palm through the first interosseous space (Fig. 4a).

In the 20 specimens of groups II, III, and IV (Table II), the above-described relationships of the radial artery were also maintained. In 7 of the 20 cases, the radial arose from the axillary artery, and in the remaining 13, from the brachial. The important departure from the pattern of vessels of group I lay in the presence of an anastomotic vessel of varying caliber which occurred in the region of the antecubital fossa (Figs. 1c, 2d, 2e). This anastomosis occurred in 2.85 per cent of the total current series as compared with Muller's 6 per cent, Ljubomudroff's 3.2 per cent, Quain's 2.5 per cent, and Gruber's low incidence of 0.5 per cent.

In those specimens in which the anastomotic artery passed anterior to the tendon of the biceps brachii muscle, several variations were observed. In most instances, the anterior anastomotic vessel was relatively large and important, and varied in length from 0.3 centimeter to 2 centimeters; in most cases, too, the caliber of the radial artery proximal to the anastomosis varied inversely with that of the connecting vessel. Where the anastomosis was very prominent, the proximal portion of the radial artery was slender, a condition encountered in 5 of the specimens (Fig. 1c). These proximal segments of radial artery were named the *vasa aberrantia* by Haller (1753).

A variation in origin of the recurrent radial artery was noted in relation to the anastomotic vessel; in 10 of the 14 cases possessing this type of union, the radial recurrent artery arose from the anastomotic vessel within 1 centimeter of its junction with the radial artery (Fig. 1d). In only a single instance was there any marked change in the caliber of the anastomotic artery after emergence of the recurrent vessel.

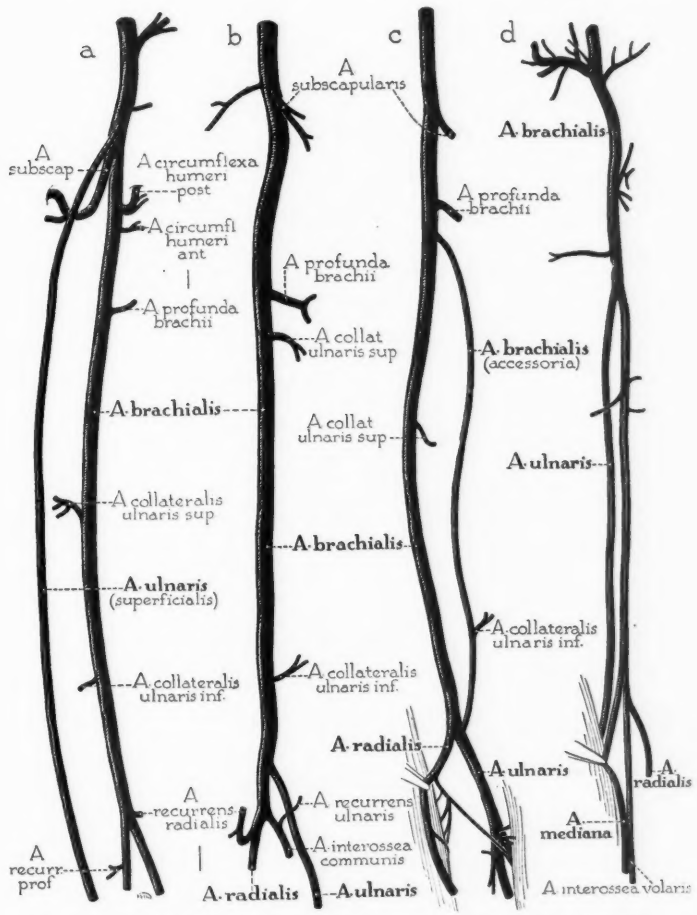

Fig. 3. a, c, d, Variations in the brachial arterial pattern, continued. b, Regular, or "normal," pattern. Dissections schematized to the extent noted in the legend for Figure 2. The specimens departed from the anatomic norm, as recorded in b, in respect to the following features: a superficial ulnar artery in a, which originated from the axillary artery; in c, a looping accessory brachial artery, which, smaller than the companion vessel, joined the ulnar artery in the cubital fossa; in d, a radial artery of high origin which divided in the cubital fossa, into median, superficial radial, and volar interosseous branches.

The uniting vessels which coursed posteriorly to the biceps tendon formed a sling-like loop around the tendon, and passed anteriorly and medially again to join the radial artery (Fig. 1d). These vessels were slender and varied in length from 2.5 to 5 centimeters; they were invariably associated with the radial recurrent artery. A very marked change in the diameter of the vessel occurred distal to the origin of the radial recurrent artery, the anastomotic channel becoming as slender as a pencil-lead at the point of junction with the radial artery proximal to the anastomosis. This peculiar type of union occurred in 4 extremities, all on the left.

In a single instance, the radial artery, at a point 35 centimeters distal to its origin from

the axillary artery, received an obliquely directed anastomotic vessel, 3 centimeters in length, which arose from the median artery 5 centimeters distal to its origin from the common interosseous artery. Dieulafe and Cahuzac (1931) reported a similar case. In 31 extremities (4.43 per cent) a prominent median artery was observed. In 7 of the 31 cases the artery pierced the median nerve in the proximal one third of the forearm.

Superficial ulnar artery. An unusual origin of the ulnar artery occurred in 17 specimens, for an overall incidence of 2.26 per cent (Figs. 2a and 3a). These results are comparable with the following, previously recorded, series: Adachi, 0.7 per cent; Quain, 1.7 per cent; Gruber, 2.1 per cent; Muller, 2 per cent, and Coulomba (1934), 3.4 per cent. In 5 cases of origin from the axillary artery, 2 were right and 3 were left extremities (Fig. 3a); in 8 specimens in which the superficial ulnar artery arose from the brachial, 5 were right and 3 were left extremities (Fig. 1a, Table III).

Although the general anatomic relationships of the superficial radial arteries were very similar, some important variations did occur in their course. By virtue of their origin, those which arose from the axillary artery established intimate relationships with elements of the brachial plexus. Without exception, they were derived from the anterior aspect of the axillary artery, and coursed between the contributions from the lateral and medial cords of the median nerve. In a single instance, an ulnar artery which arose from a brachial artery followed the same general course proximally, because the cords of the median nerve united distal to the level of origin of the artery (Fig. 1a). In the other specimens the ulnar artery arose from the anteromedial aspect of the brachial artery, usually at a proximal level.

The course of the ulnar artery of high origin through the arm was relatively constant; it remained ventral to the brachial artery and median nerve, and just dorsal to the medial border of the biceps brachii muscle, to which muscle it supplied nutrient branches. In the distal portion of the arm the artery tended to become more medially located with reference to the median nerve and brachial artery. In most instances the nerve lay lateral to the brachial artery in the proximal part of its course and crossed to the medial side of the artery at the level at which the ulnar artery also assumed a more medial course. As a consequence, the ulnar artery was the more medial of the vascular structures entering the forearm, and the median nerve lay between it and the brachial artery (Fig. 1a). In a single specimen, however, the ulnar artery arose 1 centimeter proximal to the intercondylar line from the medial surface of the brachial artery, and immediately crossed over the median nerve to enter the forearm in the manner common to the ulnar artery in other specimens.

The antebrachial continuation of the arteries exhibited variations which require special consideration. For example, whereas the radial artery of aberrant origin maintained the same general course as the so-called "normal" vessel (Fig. 3b), the relationships of the ulnar artery of unusual origin were strikingly different from those of the normal counterpart. In 11 cases, the ulnar artery coursed obliquely medialward, immediately beneath the antebrachial fascia, over the origins of the pronator teres and flexor sublimis muscles to gain the lateral border of the flexor carpi ulnaris muscle at midforearm level. The artery then either maintained this relationship or became partially covered by the muscle. Distally, the usual relationship to the ulnar nerve was attained, the vessel entering the hand in the ordinary manner. In 1 instance, the ulnar artery coursed superficial to the flexor group of muscles and passed deep to the muscular origin of the palmaris longus muscle, thereupon following a course similar to that just described (Fig. 1a). These vessels represented striking examples of the presence of major arteries where normally none are found.

Accessory brachial artery. The single example of this anatomic rarity (Fig. 3c) arose from the brachial artery 21 centimeters above the intercondylar line. Throughout its course it lay medial to the main brachial artery; however, midway in the arm it passed deep to the median nerve, and 4 centimeters proximal to its termination, crossed back over the median nerve and gave off a medially directed muscular branch. It rejoined the brachial artery in

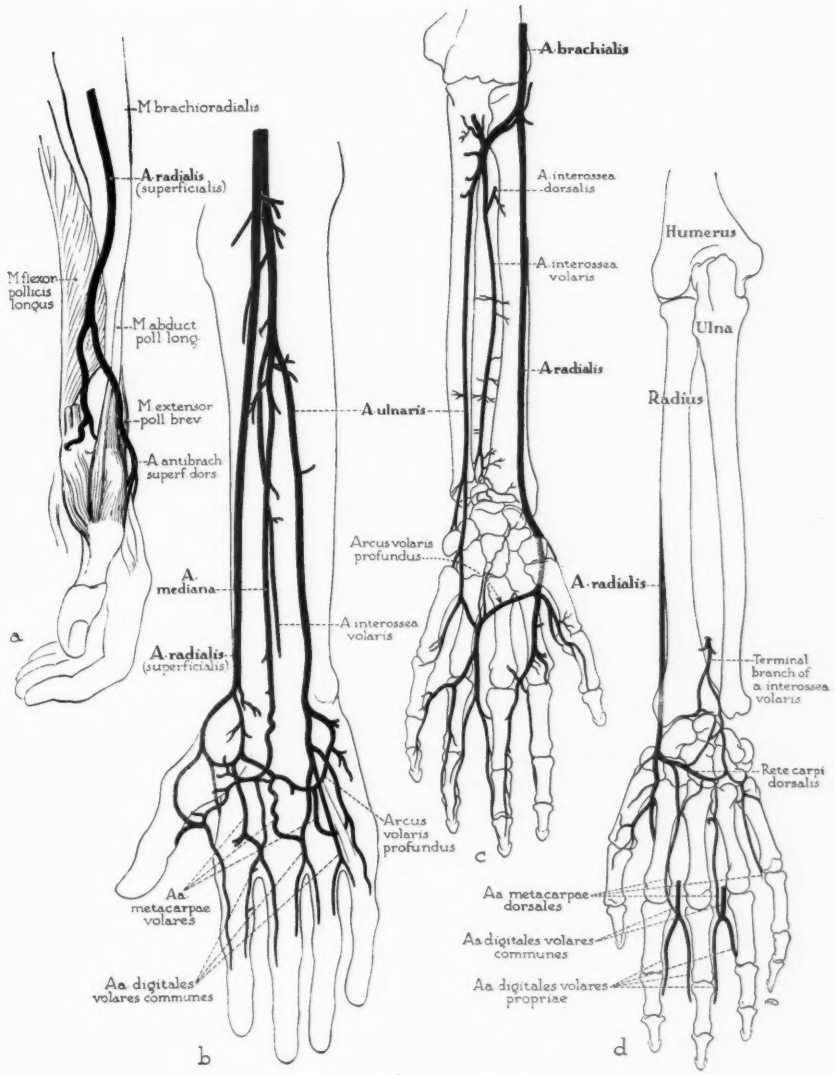

Fig. 4. Variations, in the forearm and hand, of arteries derived from the brachial or from the divisions of the latter. In a, the vessels are shown in relation to certain muscles; in c and d, they are superimposed upon the skeletal elements. The following features are depicted: in a, a radial artery, superficial throughout its course, with a dorsal manual continuation of large caliber (compare Fig. 1a); in b, a median artery which contributes to the radial segment of an incomplete superficial volar arterial "arch" and a radial artery of high origin and superficial course; in c, a deep volar arterial arch, which, in the absence of a superficial arch, gave origin, through a reduced number of metacarpal branches, to all of the digital arteries; in d, the dorsal carpal rete (of the same extremity) to which the terminal branch of the volar interosseous artery makes considerable contribution, the ulnar being an incidental contributor.

TABLE IV.—VARIATIONS IN ORIGINS OF BRACHIAL BRANCHES

Type	No.	Per cent of variations	Per cent of total
I. Superficial brachial artery	8	5.75	1.07
A. Origin from axillary artery Right: 0; Left: 1	1	0.72	0.13
B. Origin from brachial artery Right: 5; Left: 2	7	5.03	0.94
II. High origin of radial artery	107	77.00	14.27
A. From axillary artery Right: 2; Left: 14	16	11.51	2.13
B. From brachial artery Right: 54; Left: 37	91	65.49	12.14
III. High origin of ulnar artery	17	12.22	2.26
A. From axillary artery Right: 4; Left: 3	7	5.03	0.93
B. From brachial artery Right: 6; Left: 4	10	7.19	1.33
IV. Accessory brachial artery Right: 1; Left: 0	1	0.72	0.13
V. Partial duplication of radial artery Right: 4; Left: 2	6	4.31	0.8
	139	18.53	100.00

Total right: 76 54.7 per cent
Total left: 63 45.3 per cent

the antecubital fossa 23 centimeters beyond its point of origin. The radial artery arose at the level of this terminal anastomosis.

Unusual terminal branches of the radial artery. In 6 specimens there occurred anomalous terminal distribution of the radial artery. In 5 of the 6 specimens, the radial artery divided in the distal fourth of the forearm into two large branches (Fig. 4a), one of which (the medial branch) continued along the medial border of the brachioradialis muscle tendon and in a position superficial to the tendons of the dorsal long muscles of the thumb, to enter the deep aspect of the palm between the origin of the first interosseous muscle and the head of the second metacarpal bone. Proximally, in each instance, the lateral branch provided a strong contribution to the thumb and index finger, and within the palm constituted the radial portion of the deep volar arch. In 1 of the 5 specimens, the radial artery arose from the brachial 16 centimeters above the intercondylar line.

The sixth specimen possessed an almost complete duplication of the radial artery throughout its length. The radial artery, 1 centimeter beyond its origin, divided into two large components which continued in close association into the distal one fourth of the forearm; at the latter point, the two vessels passed into the wrist in the manner of those described. Before entering the palm to form the deep arch, the lateral vessel gave off the principal artery of the thumb, the artery of the index finger, and a contribution to the superficial volar arterial arch.

Fate in the hand. In 80 of 750 specimens the relation of the major arteries to the superficial volar arch was studied. Considerable departure from the so-called "normal" was observed; in only 15 specimens was a volar arch formed in the usual manner by a branch of the radial artery, which, crossing superficial to the volar carpal ligament, and anastomosing with the ulnar artery in an arciform manner, supplied the common digitals to the fingers.

In 41 cases a superficial volar arch was formed by a delicate arterial twig contributed to the ulnar artery; the small vessel arose dorsally from the radial artery, at the level or origin of the *arteria princeps pollicis* and *arteria volaris indicis radialis*, and passed into the palm distal to the insertion of the adductor pollicis muscle. In very few instances did this anastomotic twig attain a diameter of 2 millimeters. In 6 cases the arch was formed as in the 41 cases just described, but reinforcement at the midpoint of the arch was provided by a median artery which entered the palm. In 5 specimens the superficial arch was formed by anastomosis of a dorsal radial contribution and a median artery which gave origin to the first common digital artery (Fig. 4b). The ulnar artery supplied the other two common digitals separately. In 3 cases a superficial volar arch was formed by anastomosis of the ulnar and median arteries only; together they gave rise to all of the common digitals in the absence of a contribution from the radial artery. In a single instance, the arch was an anastomotic connection between a median artery and a volar contribution from the radial artery (first common digital only); in another case the arch was formed by union of 3 vessels, the ulnar, the median, and a volar contribution from the radial artery. In the

remaining 8 specimens, a superficial volar arch was wanting.

In a typical case (Fig. 4c), the deep volar arch was formed by the anastomosis of a sturdy deep component of the radial artery and an attenuated ulnar artery. The dorsal view of this specimen (Fig. 4d) revealed the formation of a dorsal carpal rete from components of the radial, ulnar and volar interosseous arteries. Two large common volar digital arteries emerged from corresponding volar metacarpal branches of the isolated deep volar arch.

In 1 of the 8, only a volar branch of the radial was present; the artery continued distalward as the first common digital. In 7 of the 8, the ulnar artery supplied all of the common digital arteries.

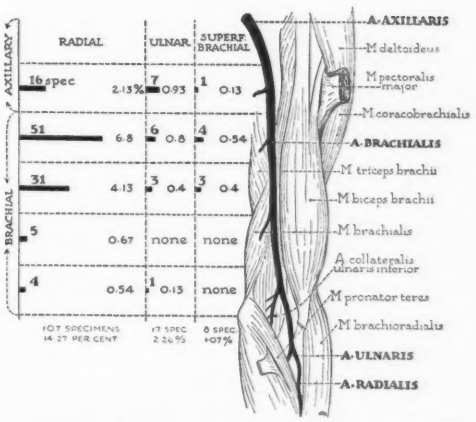

Fig. 5. Variations in the axillary and brachial levels of origin of the radial, ulnar, and superficial brachial arteries, shown graphically on the basis of the position of each in relation to 5 equal segments of the arm, and in terms of the percentage occurrence of each in the total number (750) of the specimens studied. The tabulation omits the 6 instances of duplication of the radial artery and the single case of accessory brachial.

DISCUSSION

A knowledge of the major arterial variations should be considered essential in certain surgical procedures on the upper extremities. Their importance lies in the fact that a large artery may occur where the existence of a capacious vessel would not ordinarily be expected. Because the greater number of aberrant radial and ulnar arteries arise in the proximal half of the arm, the occurrence of accessory major vascular channels through the greater extent of the arm is precluded. Consequently, serious secondary hemorrhage might occur in the depths of a wound when the operator has successfully ligated or identified only those vessels which are normally encountered in the area. It might also lead to confusion in establishing proper relationships were such an aberrant artery found in intimate association with formed elements of the median nerve, or were the median nerve clasped between two or more arteries of major caliber.

Of practical importance, also, is the common occurrence of arterial variations in two other areas; namely, the antecubital region and the dorsolateral aspect of the wrist and hand. Large anastomosing vessels occur in the former situation, and aberrant superficial vessels in the latter.

Brunati (1937) and Hazlett (1949) have summarized additional complications which may arise as a result of anomalous arteries in the cubital fossa. Unless careful scrutiny of the antecubital area is made preceding simple venipuncture, there is the possibility of entering an aberrant ulnar artery. This accident is facilitated by the superficial course of the ulnar artery of high origin, and by its rather consistent relationship to the medial basilic and medial antebrachial veins, lying immediately lateral to the latter vessel.[1] The brachial artery itself may be located superficially in the cubital fossa just medial to the biceps tendon.

That intra-arterial injection of diagnostic or therapeutic preparations may be of profound clinical significance is forcibly illustrated by Cohen's paper (1948), in which are described the catastrophic sequelae of accidental intra-arterial injection of pentothal sodium in 12 cases. Gangrene of fingers, hand, and forearm occurred in 5 of these cases with subsequent amputation; gangrene of one or more fingers was observed in 4 cases and required operative

[1]Hazlett has pointed out that the pulsation in the superficial ulnar artery was readily discernible on palpation, whereas the application of a tourniquet to the arm obliterated pulsation in the superficial artery.

Some of the early illustrations (Tiedeman) show traumatic aneurysms which developed in an era when needles were duller and blood-letting a common therapeutic procedure.

removal. Contraction deformities of the fingers and atrophy of antebrachial musculature resulted, each in a single case. In at least 5 cases the injection was probably made into a superficial ulnar artery and in 5 cases into the brachial artery.

Gangrene of the fingers has also followed accidental intra-arterial injection of contrast media for roentgenography.

SUMMARY

1. In a series of 750 consecutive upper extremities, 139 (18.53 per cent) possessed major variations in the brachial or antebrachial arterial patterns (Table IV).

2. In 364 cadavers, with both upper extremities represented, arterial variations occurred bilaterally in 23 (6.23 per cent), and unilaterally in 89 (24.45 per cent), for a total incidence of 112 (30.77 per cent). In general, departures from the anatomic norm occurred more often on the right than on the left side in a ratio of 1.2:1.

3. The following common variations were encountered in 628 extremities: high origin of the radial artery in 15.45 per cent; high origin and unusual course of the ulnar artery in 1.9 per cent; a superficial brachial artery, forming a common trunk for both radial and ulnar arteries in 1.27 per cent.

4. The surgical significance of several of the striking variations is recorded.

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THE USE OF TRACHEOTOMY IN THE TREATMENT OF CRUSHING INJURIES OF THE CHEST

B. NOLAND CARTER, M.D., F.A.C.S., and JEROME GIUSEFFI, M.D., Cincinnati, Ohio

IT need hardly be pointed out that in our present civilization, injuries resulting from severe compression of the chest are steadily increasing. However, the surgical treatment of crushing injuries of the thorax has not kept pace with advances in other branches of thoracic surgery. It was with some enthusiasm, therefore, that the authors recently presented an approach in therapy that is simple, is based upon physiological principles, and has proved highly effective in their experience with 6 cases. Since the management of patients with crushed chest is so often carried out by the general surgeon called in because of the associated injuries, it seems important at this time to present a more complete report on this method of therapy, based on results with a larger series of cases.

"Crushed chest," "flail chest," and "stove-in chest" are synonomous terms designating a form of nonpenetrating thoracic injury characterized by multiple rib fractures, which cause the movement of a portion of the thoracic wall to be paradoxical to the normal excursions of the thoracic cage. These injuries frequently result from severe compression of the thorax and are commonly associated with trauma to the head, extremities, or viscera of the abdomen and thorax, often in variable combination and degree. For this reason, any categorical analysis is difficult. A multiplicity of complications including hemothorax, simple or tension pneumothorax, and "wet lung" may predominate in a particular case and demand accurate supplementary therapy (Fig. 1). The respiratory problem, however, presents a clinical picture which is uniform enough to warrant description. Breathing is short and rapid and is, in the conscious patient, associated with great pain and apprehension. Paradoxical movement of the thoracic wall in the area of injury is apparent on inspection; and on palpation, the presence of bony crepitus identifies the segmental fractures of ribs. Cyanosis, tachycardia, and high respiratory rate are generally present. Coughing, or any increased respiratory effort, greatly increases both the pain and the paradoxical movement of the affected segment of the thorax. Initially, the tracheobronchial tree is dry, unless of course, there has been coexistent parenchymal injury to the bronchi or lung; later, however, it may become filled with secretions. This latter clinical development was recognized by Brewer and his co-workers, who termed it "wet lung." The presence of such complication, in addition to critical injury already present, establishes a vicious cycle. The cyanosis and breathing effort arising from the paradoxical respirations causes the "wet lung" syndrome; this, calling for greater effort by the patient, results in increased paradoxical movement of the injured segment of the chest wall. Pain renders coughing ineffectual; and the tracheobronchial tree is, therefore, imperfectly cleared, so that secretions stagnate and plug the alveoli and bronchioles, thus further impairing the mechanical ventilation of the lung.

Crushing injuries of the chest are serious and are attended by a high mortality. A great number of therapeutic measures have been recommended and tried. These progress from simple adhesive strapping to complicated forms of operative skeletal fixation. No attempt will here be made to review these many procedures; suffice it to say, that none has gained widespread acceptance, for although many are effective for single objectives, they fail to encompass all of the physiological problems associated with such injuries.

In order that the aims of any program of therapy may be properly understood, it is well to emphasize the major pathological problems which confront the surgeon. In any

From the Department of Surgery, College of Medicine of the University of Cincinnati, and the Cincinnati General Hospital.

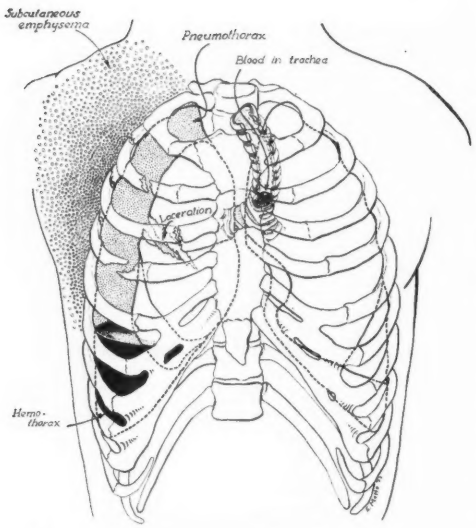

Fig. 1. Composite representation illustrating some of the common complications to the respiratory system in patients suffering with crushed chest, (1) pneumothorax, (2) hemothorax, (3) subcutaneous emphysema, (4) laceration of the lung, and (5) blood in the tracheobronchial tree.

case of severe crushing injury of the thorax, certain factors are involved which operate to reduce respiratory reserve. These are: (1) paradoxical movement of the chest wall, which interrupts the efficiency of the chest bellows; (2) severe pain arising from the movement of fractured ribs, which further impairs attempts at increased respiratory effort; (3) copious tracheobronchial secretions, which may result immediately from parenchymal injury of the bronchi or lung, or may develop later in the "wet lung" syndrome. In either instance, the effect is the same, namely, to reduce satisfactory aeration.

In individual cases, there may also be hemothorax, pneumothorax, either simple or tension, and severe parenchymal damage of the lung. All of these complications tend to reduce the number of functioning alveoli, and thus even more drastically reduce the respiratory reserve.

It is clear that provision for *adequate respiration* remains the fundamental objective in any treatment of thoracic injury. Since 1949, tracheotomy, as a primary form of therapy, has been utilized with gratifying success by the authors in the treatment of crushing injuries of the thorax. Clinical and experimental experience has indicated that the simple procedure of tracheotomy will efficiently oppose the major *pathological* factors just enumerated by: (1) reducing the paradoxical movement of the injured chest segment; (2) alleviating pain, since it decreases the movements of the fractured ribs; and (3) providing an easy and ready method of aspirating tracheobronchial secretions. This latter advantage of tracheotomy has received widespread interest recently, as evidenced by its use in many diversified conditions, including tetanus, head injury, and postoperative esophageal resection. The importance of tracheotomy in maintaining a clear tracheobronchial tree cannot be minimized.

Tracheotomy also provides certain *physiological* advantages hitherto unrecognized. It is interesting that although it is a time-honored surgical procedure, no recognition has been given to its basic function of effecting alterations in ventilation. Recently, the authors presented clinical and experimental evidences indicating the manner in which tracheotomy alters respiratory physiology in certain varieties of ventilatory distress (2). Analysis of the data, both in animals and man, indicates that the improvement resulting from tracheotomy is primarily associated with two fundamental changes: (1) a reduction in volume of dead space involved in the respiratory act, i.e., that of the nasal passages, mouth, pharynx, trachea, and tracheobronchial tree; and (2) a decrease in resistance to the inspired and expired air.

In the normal subject with a tidal air of 500 cubic centimeters or more, the presence of a dead space of roughly 150 cubic centimeters is tolerated without difficulty. This dead space in no way contributes to ultimate oxygenation, and represents unnecessary work. Therefore, in patients able to ventilate only with abnormally reduced tidal air, this constant dead space becomes more and more detrimental to the efficiency of the impaired ventilatory act. In severe crushing injuries of the thorax, the tidal air may be seriously decreased as the result of: (1) interruption of

the efficiency of the thoracic bellows by the paradoxical movements of the injured chest segment, and (2) voluntary diminution of respiratory effort, resulting from severe pain associated with movement of fractured ribs.

Additional factors producing respiratory embarrassment such as "wet lung," pneumothorax, hemothorax, and pulmonary injury have already been cited. When these are present in combination with low tidal air, respiratory difficulties are increased. Determinations of tidal air with a Collins spirometer made in Cases 4 and 5, described later, were found to be 320 cubic centimeters and 330 centimeters; whereas in 2 patients with less severe injury who did not require tracheotomy, the tidal air was found to be 500 and 540 cubic centimeters respectively. It is interesting that in the latter 2 patients, vital capacity did not exceed 700 cubic centimeters, which emphasizes the fact that although they were tolerating their injuries satisfactorily under the circumstances then present, their respiratory reserve on a mechanical basis was indeed small.

When the point of entrance of respired air is changed from the nose and mouth to the trachea just above the suprasternal notch, the dead space is reduced about 100 cubic centimeters. This figure was determined by observations on autopsy specimens. The esophagus was ligated at its origin from the hypopharynx, and the mouth tracheopharynx was then filled with water to the point of the usual tracheotomy stoma. *With the mouth in the position of easy mouth-breathing,* this volume was found to be 110, 115, and 125 cubic centimeters in 3 men recently deceased. Although these figures cannot be taken as absolute, they do indicate that a substantial reduction in dead space is effected by tracheotomy. This decrease in dead space contributes to the more effective utilization of the tidal air, whether it is of normal or diminished amount. *The more effective utilization of a tidal air, which is reduced to levels incompatible with adequate ventilation by diminishing the volume of dead space, appeals to the authors as an important physiological effect of tracheotomy* (Fig. 2).

The second important physiological alteration which takes place with tracheotomy is a

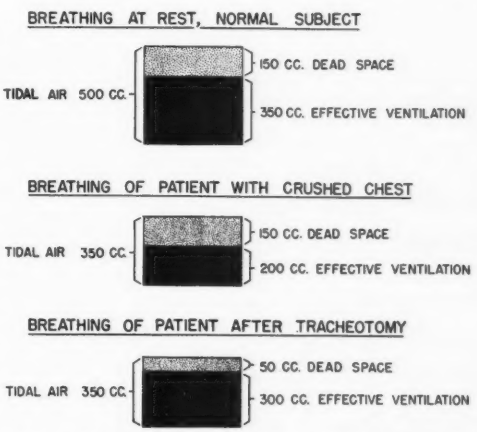
BREATHING AT REST, NORMAL SUBJECT
TIDAL AIR 500 CC.
150 CC. DEAD SPACE
350 CC. EFFECTIVE VENTILATION
BREATHING OF PATIENT WITH CRUSHED CHEST
TIDAL AIR 350 CC.
150 CC. DEAD SPACE
200 CC. EFFECTIVE VENTILATION
BREATHING OF PATIENT AFTER TRACHEOTOMY
TIDAL AIR 350 CC.
50 CC. DEAD SPACE
300 CC. EFFECTIVE VENTILATION

Fig. 2. Schematic representation indicating presumed method by which decrease in dead space operates to increase effective ventilation in patients with low tidal air.

rather profound reduction in resistance to breathing. Any such reduction should be reflected in the intrapleural pressure. Studies on intrapleural pressure and intratracheal pressure, both in animals and in man, leave little doubt that a major proportion of the resistance in the respiratory tree is located above the point of the usual tracheotomy. Following tracheotomy, the intratracheal pressure variations that occur with breathing are practically nil; and the intrapleural pressure oscillations are roughly reduced one-half (Fig. 3). Early in our investigations of patients with crushed chest, the precaution of examining the larynx was taken in order to make certain that the larynx functioned properly. It was discovered that in such instances (Cases 4 and 5) the cords functioned efficiently as they were wide apart and moved rhythmically with breathing, in an attempt to part even wider on inspiration. The reduction in resistance, however, is easily correlated with well known principles of gas flow within tubes. It is recognized that resistance varies inversely to the diameter of the tube, and is also dependent upon turbulence. In man, the efficiency of the larynx in the respiratory system has suffered in deterence to its function of phonation; and in its normal physiology, it represents the narrowest point in the upper air passages, acting as a virtual bottleneck to the oscillating

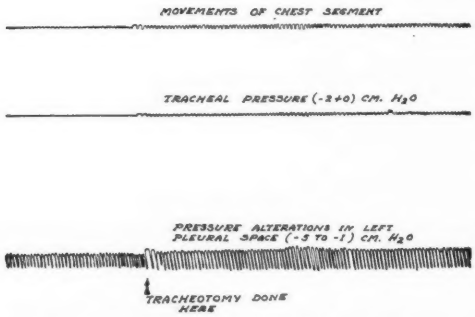
MOVEMENTS OF CHEST SEGMENT
TRACHEAL PRESSURE (-2+0) CM. H_2O
PRESSURE ALTERATIONS IN LEFT PLEURAL SPACE (-3 TO -1) CM. H_2O
TRACHEOTOMY DONE HERE

Fig. 3. Kymographic tracing showing marked decrease in paradoxical motion of chest wall effected in experimental animal by performance of tracheotomy. Notice also the abrupt fall in both intratracheal and intrapleural pressures.

movements in the air column. In addition, the innumerable convolutions of the larynx, pharynx, and nose and mouth are ideally suited to promote turbulence and to increase resistance to gas flow in this manner. Thus it has been estimated that approximately three-fourths of the resistance to breathing is located in the upper air passages. It is easy to understand therefore how the defunctioning of these passages decreases resistance to the inflow and outflow of air, thereby contributing to better aeration. Again it is to be emphasized that, in those cases in which adequate pulmonary function is maintained with difficulty, any factor which contributes to more efficient respiration may be the determining factor in survival.

A dramatic corollary to the more efficient functioning of the respiratory system is the lessened excursion of the loose segment of the thoracic wall. This results from a decrease in dead space and especially from the diminished resistance to inflow and outflow of respired air. It has been a striking phenomenon clinically and also in experimental animals. The paradoxical movements of the free segment of the thoracic cage are so greatly decreased after tracheotomy that the need for complicated forms of skeletal fixation is eliminated. It is believed that such a decrease is a potent factor in survival, and is associated with lessening of the respiratory effort necessary for adequate ventilation. In consequence, the greater ease of respiration and lessened movement of the fractured ribs result in marked lessening of pain and apprehension, a factor of real importance in contributing to better aeration.

The treatment of crushing injuries of the chest taxes the ingenuity of the surgeon even though he may be well versed in surgery of trauma. It is likely that one or more of the body systems may share in the injury, and will require concurrent treatment that must maintain a prospective, designed to secure life and restoration of function to the best degree possible. It is likewise a fact that treatment must be individualized, and that no fixed set of rules for therapy can be devised. In general, the approach that the authors have used in dealing with the respiratory problems is as follows. If the chest injury is of *minor* or of moderate degree, so that adequate aeration constitutes no problem, the patient is generally treated with intercostal nerve block and is carefully observed. If, subsequently, cough is inadequate to raise secretions properly and respiratory function shows any sign of being jeopardized by the accumulation of tracheobronchial exudate, tracheotomy is then instituted without hesitation. It has been observed that this therapeutic measure is best applied before serious respiratory imbalance occurs. If the chest trauma is of the *severe* variety, tracheotomy is instituted at once. In practically every instance, this has resulted in immediate improvement of respiration and systemic condition. Oxygen is generally supplied through the tracheotomy tube, and blood and fluids are administered in conformity with the over-all picture. On admission, a fair proportion of these patients will manifest subcutaneous emphysema and physical signs of pneumothorax or hemothorax. Under such circumstances, the pleural cavity involved is aspirated in order to secure information with regard to the presence of air or blood, and to determine whether the amounts present or whether the intrapleural pressure may not be leading factors in the respiratory distress. This simple diagnostic maneuver provides valuable information immediately, obviates the necessity for moving the critically ill patient to x-ray, and establishes the timely diagnosis of tension pneumo-

thorax or massive hemothorax. If evidence is found of a rapidly spreading subcutaneous emphysema, or of a rapidly accumulating pneumothorax with or without tension, a small intrathoracic catheter is inserted under local anesthesia and is connected to waterseal drainage. This has proved to be advantageous in the presence of spreading subcutaneous emphysema, in that the escape of air from the pleural space is directed from the tissue and siphoned off into the drainage bottle, rather than allowed to distend the soft tissue progressively. When it is obvious that the escape of air from the lacerated lung has ceased, the thoracotomy tube is utilized, along with suction, to promote rapid expansion of the collapsed lung.

The tracheotomy tube is removed when the general condition of the patient has improved, after the breathing difficulties have been resolved, and when fixation of the rib fractures has occurred sufficiently so that paradoxical respiration and pain do not reappear. Eleven patients with crushing injuries of the thorax have been treated by tracheotomy, 5 of the cases having been previously reported (2). All 11 cases are now completely recorded, in order to emphasize the variety of the injuries and to demonstrate some of the features in treatment which just have been cited.

CASE REPORTS

CASE 1. L.K. (246807, previously reported). This 58 year old white man was admitted on January 11, 1949, following an automobile accident. He complained of pain over the anterior aspect of the thorax and over the sacrum posteriorly. Roentgenological examination revealed a fractured left pelvis involving the superior and inferior rami, and a fracture of the transverse process of the fifth lumbar vertebra on the left. Blood pressure was 120/90; pulse 116 at the radial artery and 130 at the apex; respirations were 36. The patient was obese, with rapid short respirations, conscious, and cooperative. He was receiving oxygen per nasal catheter, and his color was satisfactory. Examination of the thorax showed bony crepitus of the anterior wall bilaterally, involving the upper ribs. There was pain on pressure over the sternum. No paradoxical respirations were recognized at this time; the thorax was clear to auscultation. The heart sounds were irregular, with an apparent pulse deficit. Roentgenograms showed fractures of ribs 3, 4, 8, and 9 in the anterior axillary line on the right, and of 3, 4, and 6 in similar position on the left. In the next 12 hours, respirations became increasingly difficult, dyspnea and pain were more apparent, and cyanosis appeared despite administration of oxygen. Paradoxical movement of the anterior thoracic wall now became noticeable. The tracheobronchial tree, however, remained clear. A tracheotomy was done at this time; and although aspiration failed to produce any significant amount of secretion, the procedure produced a great deal of respiratory relief. Respirations were much less labored, and the sucking motion of the thoracic wall almost abated. The patient's color was immensely improved and his apprehension gone. Progress thereafter was steady, and the tracheotomy tube was removed 16 days later.

CASE 2. H.K. (246896, previously reported). This 61 year old white man was admitted on January 15, 1949, following an automobile accident. He was unconscious on admission. The left pupil was slightly larger than the right, and the Babinski test was positive on both sides. Severe cyanosis was present; blood pressure was 125/90. He was given oxygen by mask, and within an hour he began to regain consciousness, shortly becoming awake and responsive, but unable to talk except in guttural tones. Respirations were jerky and predominantly diaphragmatic; he was markedly cyanotic when not receiving oxygen. There was bony crepitation in the region of the upper 4 ribs, in the costochondral area on the right. Respirations were paradoxical in this area. There was an acromioclavicular separation on the right, with an irregular dirty laceration on the right buttock, through which a large comminuted fracture of the sacrum protruded. The latter wound was hastily débrided under local anesthesia and left open. This patient's condition at this point began to deteriorate rapidly. Respirations became labored, and he had to be restrained because of excitability. Examination now revealed considerable subcutaneous emphysema of the right thorax and neck. Blood pressure was 120/90, respirations 36, pulse 108. Thoracentesis on the right produced 1,000 cubic centimeters of air which was not under tension, but no particular improvement followed this procedure. The patient steadily grew worse until he was considered to be *in extremis*. Tracheotomy was performed, with immediate and spectacular improvement. Respirations became quiet and easy, excursions diminished, his color changed from cyanotic to normal, restlessness disappeared, and he was without pain. Crepitation lessened, the emphysema ceased to extend, and his improvement was steady, though slow. Oxygen was discontinued 2 days later, but digitoxin was necessary because of the patient's development of fibrillation. The tracheotomy tube was removed on the fourteenth hospital day; he was discharged on February 1, 1949.

These were the first 2 patients treated with tracheotomy. Decision to do so was empirical

It is important to point out that no abnormal secretions, either as to character or

amount, were present before or after tracheotomy; so that the standard advantage of tracheotomy, that is, relief of obstruction, was obviously not involved here. The spectacular improvement incident to so simple a procedure was amazing and prompted continued use and experimental investigation. Certain sequential effects have been uniformly observed. Following tracheotomy, respirations which previously have been short, grunting, and noisy became shallow, quiet, and painless. The paradoxical segment is stabilized, and it is doubtless this relative fixation that promotes the relief of pain. Generally, the patient's color is noticeably improved almost immediately. The agitation often present (believed to be due to cerebral hypoxia) is terminated, and the patient relaxes in gratified sleep.

CASE 3. L.M.N. (previously reported). This 53 year old white man was admitted on May 2, 1949, in an alcoholic condition. The police reported that he had driven his car into a streetcar. He was only partially co-operative, and complained of pain in his chest. There was marked respiratory difficulty, but no paradoxical motion and no cyanosis. The trachea was in the midline. There was crepitation in the anterior axillary line bilaterally, with subcutaneous emphysema. Respirations were diaphragmatic. Roentgenograms showed fracture of ribs 4 and 5 on the right, and 3, 4, 5, and 6 on the left. Respiratory difficulty increased in the following 48 hours, in spite of oxygen therapy. Paradoxical motion became apparent, the patient's thorax became filled with coarse rhonchi, and he became markedly cyanotic and dyspneic. Tracheotomy was performed, and a large amount of mucus was aspirated from the tracheobronchial tree. Respirations became easier immediately, and aspiration continued to be necessary only at frequent intervals. He did well thereafter and left on the twelfth hospital day.

Paradoxical respiration was not evident in this instance until the "wet lung" syndrome occurred, with the concomitant, increased, respiratory effort. Undoubtedly, the accumulation of tracheobronchial secretions was the important factor for which tracheotomy was particularly useful. The importance of tracheotomy under such circumstances cannot be overemphasized. It obviates the need for repeated bronchoscopy, and permits frequent and simple aspirations of the tracheobronchial tree to be performed by the nursing staff. Bronchial secretions which otherwise stagnate can be removed, and the complications of atelectasis and consequent pneumonia can be averted.

CASE 4. L.S. (262207, previously reported). This 45 year old white woman was admitted to the receiving ward on March 26, 1950, following an automobile-train accident. She was comatose on admission, and her breathing was rapid, with grunting respirations. She moved all extremities, was moderately restless, and responded to painful stimuli. Her pulse was 128, blood pressure 90/60, and respirations 44. There was some cyanosis, which became less noticeable after administration of oxygen. Thoracic examination revealed subcutaneous emphysema over the entire thorax anteriorly and extending into the neck. Auscultation revealed no rhonchi. Roentgenograms showed anterior and posterior fractures of ribs 2 through 5 on the right side. There was marked paradoxical movement of a large portion of the right thorax, particularly in the sternal area. Tracheotomy was performed, and immediate improvement was evident. The color of the skin became progressively better, breathing was rapid but easy, and the subcutaneous emphysema lessened. The patient's course was generally good, with notable absence of pain and apprehension. The tracheotomy tube was removed on the fourteenth day, and she was dismissed soon thereafter.

CASE 5. W.L. (268913, previously reported). This 47 year old negro man was admitted to the receiving ward on October 29, 1950, following an automobile accident. Examination revealed a crushing injury of the thorax and a severe head injury. The ribs were fractured in 3 places: right, 1, 2, 3, and 4 in the midclavicular line; left, 3, 4, 5, 6, and 7 in the anterior axillary line; and left, 3 through 9 in the midscapular line posteriorly. The patient was unconscious, with a hemiplegia on the left side. Lumbar puncture showed a pressure of 126 millimeters of water. Spinal fluid contained 10,000 red blood cells per cubic centimeter. Respirations were short, shallow, and paradoxical. He was cyanotic in spite of oxygen therapy. His condition on admission was so poor that it was doubtful whether he would survive the night. Tracheotomy was performed, however, and respirations immediately became easier, with paradoxical movement diminishing noticeably. His neurological status, resulting from severe midbrain damage, deteriorated rapidly, and he expired 4 days after admission. Necropsy revealed marked acute cerebral edema, with encephalomalacia. Pulmonary congestion was also present, as well as a small (500 c.c.) hemopneumothorax on the right.

In each of these 2 cases, there was immediate improvement in oxygenation following tracheotomy. The paradoxical movement of the loose segment of the thoracic cage was noticeably lessened, and pain was relieved. The color improved immediately, and agi-

tation and apprehension disappeared. In Case 4, *before* tracheotomy, the oxygen saturation was 85 per cent with a carbon dioxide content of 29.7 volumes per cent. *After* tracheotomy, the oxygen saturation rose to 90 per cent, despite the fact that the patient was no longer receiving oxygen, and the carbon dioxide fell to 27.9 volumes per cent.

CASE 6. Lawrence Terry (264717). This 45 year old white man was admitted to the receiving ward on June 3, 1950, after a fall from a third story window. On admission, he was in profound shock, with a blood pressure of 70/60. Oxygen and blood were started immediately and his pressure stabilized at 120/80 after 2 units of blood. He received 2 additional units during the day as supportive therapy. Physical examination revealed suppressed breath sounds over the left chest and lateral chest wall. There was tenderness over the lumbar spine and pelvis, and an obvious fracture of the left os calcis. Roentgenograms revealed the following: (1) left pneumothorax and a large area of traumatic pneumonitis in both lungs, and fracture of ribs 7, 8, and 9 bilaterally; (2) compression fracture of vertebrae D12, L1, and L2; (3) fracture of pelvis, right pubis, and ischium; and (4) fracture of left os calcis.

The patient began to have marked respiratory difficulty. Breathing was short, rapid, and grunting in character. There was no obvious paradoxical movement of the chest wall, but the subcutaneous emphysema increased progressively. His sputum was bloody and was coughed up only with great difficulty.

His left chest was aspirated of 1,000 cubic centimeters of air, which was removed under no tension. Nevertheless, he still appeared cyanotic despite administration of oxygen. A tracheotomy was then performed, with immediate marked improvement, his trachea now clearing of large amount of thick, bloody secretion. His color was much improved but his respirations were still rapid. On the third hospital day, the patient's condition suddenly deteriorated, and he had apparently developed a tension pneumothorax; this was treated by a tube thoracotomy in the third left interspace anteriorly. Thereafter, he made slow but progressive improvement. The thoracotomy tube was removed 3 days after its insertion. Respiratory difficulties appeared solved. On his tenth hospital day, he suddenly began having tarry stools; and his hemoglobin had dropped from a previous level of 11 to 7.5. Despite a negative history, he was considered to be bleeding from a duodenal ulcer, which was treated conservatively. His bleeding continued, however, and he died suddenly on his twelfth hospital day after an exsanguinating hemorrhage. Autopsy revealed: (1) left fibrinous pleuritis, (2) fecal atelectasis, (3) acute fibrinous pericarditis, (4) duodenal ulcer with massive gastrointestinal hemorrhage, and (5) fracture of ribs 7, 8, and 9 bilaterally.

Tracheotomy, although unquestionably effecting physiological improvement in respiratory exchange, was primarily important in this case as a means of clearing the tracheobronchial tree of bloody secretions incident to parenchymal injury. (The thoracotomy tube obviously should have been inserted earlier.) The importance of early treatment of complications such as extensive pneumothorax or spreading subcutaneous emphysema, by the immediate insertion of a suitable intrathoracic catheter, has been realized. By this procedure, the rapid development of tension pneumothorax is averted, and sudden catastrophes are prevented. It was felt at the time of this patient's demise that his respiratory problems were being handled without difficulty, and it was anticipated that without the complication of gastrointestinal hemorrhage, recovery was assured.

CASE 7. Edwin Harsch (269841). This 51 year old, inebriated, white man was admitted to the Cincinnati General Hospital on December 3, 1951, after having been found lying on the railroad tracks. Blood pressure was 100/70, pulse 100, and respirations 28. There was marked subcutaneous emphysema of both sides of the neck. The right clavicle was obviously fractured, and there was a bony crepitus of ribs 2, 3, 4, and 5 anteriorly at the sternal margin. A thoracentesis of the right chest was immediately performed, and 2,000 cubic centimeters of air were removed. Immediate improvement resulted in the patient's respiration, which now slowed from 28 to 16. Cyanosis, which had been present, disappeared. Two and one-half hours after the first thoracentesis, aspiration of the right pleural space was repeated and yielded 350 cubic centimeters of air. An intercostal catheter was now introduced under local in the fourth interspace anteriorly. Tracheotomy was held in abeyance at this time because the patient was not in severe ventilatory embarrassment, and his pain could easily be controlled with intercostal nerve blocks. Within 20 hours after admission, however, he began to develop significant amounts of tracheobronchial secretions, which he was unable to raise despite repeated tracheal aspirations with a catheter. Therefore, in order to facilitate trachea toilet, a tracheotomy was performed. There was no dramatic improvement in respirations, but thereafter the respiratory tree was kept clear without difficulty. Convalescence from this point on was unremarkable, and the patient was discharged on his sixteenth hospital day.

This patient illustrates certain interesting features which bear discussion. His injuries

were of such a nature that following the control of his pneumothorax, he had sufficient respiratory function to get along without too much difficulty. Actual measurements of his tidal volume with a Collins spirometer showed a tidal air of 550 cubic centimeters. His vital capacity, however, did not exceed 580 cubic centimeters, so that obviously his measure of respiratory reserve was extremely small. Once he began to have difficulty with tracheal secretions, his ability to maintain adequate ventilation became jeopardized, and tracheotomy was necessary to prevent him from getting into distress. In instances of this kind, tracheotomy is of inestimable value in keeping the tracheobronchial tree clean, and for preserving the patient's margin of satisfactory aeration.

CASE 8. Willie Brown (271713). This 49 year old negro man was admitted to the Cincinnati General Hospital, after having been thrown from an automobile. He sustained a crushing injury of the thorax over the right chest posteriorly. Blood pressure on admission was 110/80, and respirations 32. There was marked subcutaneous emphysema and paradoxical motion of the right chest wall posteriorly. Comminuted fractures of ribs 6 through 9 could be palpated in the posterior axillary line. Excursions of the right chest were limited. A thoracentesis was immediately performed, and 500 cubic centimeters of air was removed; whereupon, a thoracotomy tube was inserted under local into the third right interspace and connected to underwater drainage. The patient then drained a small amount of air into the floor bottle, and approximately 450 cubic centimeters of dark bloody fluid was obtained. He was observed thereafter on the ward for a period of approximately 4 hours. Despite the administration of oxygen, his chest pain continued and his respiratory rate rose from 36 to 40. Excursions of the thoracic cage were shallow and rapid, with rather marked paradoxical movement posteriorly. The nail beds were cyanotic. A tracheotomy was then performed; respiratory improvement was striking, slowing to 24. Chest movements were shallow and easy. Paradoxical movement of the flail segment was tremendously diminished. The color of the nail beds was improved and the patient lay quietly without apprehension. Aspiration of the trachea immediately following tracheotomy, failed to obtain any significant amount of tracheobronchial secretion. Chest x-ray films revealed fracture of ribs 5 through 10 on the right, with marked proximal dislocation of 6 through 9. The patient's course thereafter was remarkably benign. The thoracotomy tube was removed in 72 hours, the tracheotomy tube 10 days after admission, and he was discharged 2 days later.

CASE 9. James Coyle (254164). This 57 year old white man was admitted on May 11, 1951, after an automobile accident. When first examined, he was in moderate shock, with a blood pressure of 88/60, pulse of 112, and respirations 32. There was marked paradoxical motion of the right anterior chest wall, sternum, and costal cartilages below the level of the second rib. Subcutaneous emphysema of the right chest was noted. There were ragged, compounding fracture wounds in the supracondylar areas of both femurs, which obviously extended into both knee joints. He was in severe pain, his respirations were short and grunting, and he was cyanotic despite administration of oxygen. A tracheotomy was performed very soon after admission, resulting in very prompt improvement in his respirations, which now became easier and slower. The paradoxical movement was now minimal. A thoracentesis was performed, and yielded 750 cubic centimeters of air from the right pleural space. Two hours later, thoracentesis was repeated and again yielded 1,400 cubic centimeters of air, whereupon a thoracotomy tube was promptly inserted under local anesthesia in the third interspace anteriorly, and attached to waterseal drainage. When stabilized, the patient was moved to the operating room, where, under local anesthesia, his wounds were very simply débrided, and the extremities casted. His course was exceedingly good, considering the severity of his injuries (roentgenograms revealed fractures of ribs 4, 5, 6, and 7 in the anterior axillary line and at the sternal margin). On May 14, 1951, his lung was well expanded, and the subcutaneous emphysema was practically nil. The thoracotomy tube was thereupon removed. On May 20, 1951, his respiratory problems were pretty well resolved, and the tracheotomy tube was removed. He was soon thereafter transferred to the orthopedic service, where he is still slowly recuperating from his fractures.

CASE 10. Charles Mashburn (274279). This 80 year old white man was brought to the hospital, after having been struck by a train. On physical examination, he was found to be in shock with a blood pressure of 70/60. He was conscious but disoriented, incoherent, unco-operative, and hyperactive. He breathed with difficulty and was markedly cyanotic. There were small lacerations of the right parietal area. Marked subcutaneous emphysema was present over the right chest, neck, and arm, down to the wrist. The trachea was shifted slightly to the left. There was marked crepitation of bony variety over the right chest anteriorly and laterally. Subsequent x-ray films revealed fracture of ribs 2 through 9, with ribs 2 through 6 of segmental variety. There was also a fracture of the right clavicle. The patient was treated initially with a unit of blood intravenously, and a tracheotomy done immediately in the receiving ward provided prompt and immediate improvement. Breathing was slower and easier. Cyanosis was now barely perceptible, and the patient heretofore agitated,

now rested quietly. A thoracentesis of the right chest removed 600 cubic centimeters of air, resulting in further improvement in his condition. About 2 hours later, respirations again became difficult, and the right chest was again aspirated; 900 cubic centimeters of air were again obtained, whereupon a tube thoracotomy was performed in the third interspace anteriorly, and the patient again showed noticeable improvement. Under water, drainage was established. Suction was applied to his thoracotomy tube 7 hours after admission, and the tube was removed on the fifth day. His course in the hospital was remarkable for a man of his age and injuries, and with the exception of a severe aspiration pneumonia which developed on the sixth day, it was excellent. His pneumonia responded to penicillin and chloromycetin. The tracheotomy tube was removed on the seventeenth hospital day, when it appeared that his rib cage was well stabilized by callus. He was discharged on the twenty-fourth hospital day, the tracheotomy stoma having healed.

These 3 patients illustrate a singularity of response that is now expected with tracheotomy. All of them had extremely severe chest injuries of a kind in which the prognosis, in previous years, was considered practically hopeless. The change in condition of these patients, marked by the institution of tracheotomy, was spectacular in each case. (Readiness to employ a thoracotomy tube, whenever indications called for such need, may also be noted in Cases 6 to 10.) From these cases, it has been learned that by this simple procedure performed under local anesthesia, the spread of subcutaneous emphysema may be prevented by diverting the escape of air from the pleural space to waterseal drainage, rather than allowing it progressively to distend the soft tissue. It has also been observed that the danger of sudden accumulation of air in the closed pleural space under tension may be eliminated; and that after 24 to 48 hours, when the escape of air from the lung surface no longer occurs, the thoracotomy tube, along with suction, may be utilized to expedite the rapid expansion of the collapsed lung.

CASE 11. George Cunningham (275698). This 21 year old negro man was admitted on June 6, 1951. Details of his injury, which occurred while he was inebriated, were unknown to him. He complained of severe pain over the sternum, and his breathing was made worse with coughing. Blood pressure was 140/90; respirations 28. There was a small ecchymosis at the right manubriosternal articulation. The body of the sternum retracted with each inspiration, and pressure over this area caused acute pain. There were large rhonchi in both lung fields. Intercostal nerve block from 2 through 6 on either side gave some relief, and thereafter respirations were noted to be somewhat deeper. Tracheal suction recovered considerable secretion, and thereafter the chest was clear to auscultation. Roentgenograms demonstrated a transverse fracture of the sternum in good position. Although the patient never did get into severe respiratory difficulty, he continued to have pain whenever he attempted to raise his bronchial secretions; and at such times, the paradoxical movement of the anterior chest wall became very marked. It was decided therefore to perform a tracheotomy in order to stabilize the sternal area, relieve him of his pain, and to make possible keeping his tracheobronchial tree clear and preventing pneumonia and atelectasis. *Stabilization of the chest wall was never more graphically illustrated.* The retraction with inspiration ceased entirely. The patient's pain was obliterated, and his trachea could thereafter, without difficulty, be kept free of secretions. The tracheotomy tube was removed on his fifth hospital day and he was discharged 10 days following admission.

In this instance, tracheotomy was utilized primarily to eliminate pain and to stabilize the oscillating sternal segment, as well as to provide a manner of keeping the trachea clean. The stabilization of the sternum by this simple method will surprise anyone who has labored to immobilize this area by skeletal fixation.

DISCUSSION

The effects of tracheotomy fall into two main categories, mechanical and physiological. The *mechanical effects* have been recognized for some time and comprise: (1) the ability to maintain a clear airway by easy removal of excessive fluids or blood from the tracheobronchial tree, and (2) the relief of laryngeal obstruction resulting from edema, bleeding, tumor, or faulty function of the vocal cords.

Survey of the literature has failed to reveal mention of the *physiological effects* of tracheotomy on the physiology of respiration. Such effects are of real importance, and we believe the principal ones to be: (1) a decrease in the amount of dead space in the respiratory tree, and (2) a decrease in resistance to breathing, both on inspiration and expiration.

An important corollary of the physiological effects is the stabilization of loose segments of the thoracic cage wherever they exist.

Although our preliminary work has been primarily associated with the effects of tracheotomy in crushing injuries of the thorax, the physiological principles ascertained from this experience imply a much broader application. Our observations and clinical experience suggest that tracheotomy may also be recommended in those instances in which paradoxical movement or low tidal volume are of serious moment. Such a condition is encountered in those cases in which too extensive rib resections have been performed in thoracoplasty or in the removal of large tumors of the sternum or ribs; they are also found in cases with unstable mediastinum in the presence of open pneumothorax. We have used tracheotomy with great success in 1 case of the latter type.

Having pointed out the various advantages of tracheotomy, it is wise to comment on certain precautions in the care of *all* patients with tracheotomy. (1) With the glottis defunctionalized, these patients are unable to cough effectively, and it is, therefore, imperative that proper aspiration of the trachea be performed at suitable intervals, or whenever specifically indicated. (2) Aspiration, however, should be performed with great care and only for short interrupted periods of suction. It has been shown by Kergin and his associates that aspiration of the tracheobronchial tree is an effective method of lowering the oxygen concentration of arterial blood quite precipitously. Coincidentally, under such states of hypoxia, vagovagal reflexes are encouraged so that the stimulation of the aspirating catheter, concurrent with suction producing hypoxia, may result in sudden cardiac arrest. One instance of such a catastrophe has been observed.

SUMMARY

1. A simple, effective, and physiological method of treating crushing injuries of the thorax is proposed, utilizing tracheotomy as the primary form of therapy.

2. Tracheotomy is highly effective in such cases because it: (a) reduces dead space; (b) decreases resistance to breathing; (c) stabilizes loose segments of the thoracic wall; (d) gives easy access to the tracheobronchial tree for aspiration of retained secretions.

3. Eleven cases of crushing injuries to the thorax are reported, with emphasis on the salient features in management.

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THE EFFECT OF CORTISONE ON THE PREVENTION OF PERITONEAL ADHESIONS

CHARLES A. HUBAY, M.D., F.A.C.S., ELDEN C. WECKESSER, M.D., F.A.C.S., and WILLIAM D. HOLDEN, M.D., F.A.C.S., Cleveland, Ohio

THE introduction of 11-dehydro-17-hydroxycorticosterone (cortisone, compound E) has led to its extensive clinical and investigative use. Ragan (8, 9) and his co-workers noted delay in the formation of granulation tissue and impaired wound healing in patients receiving cortisone or ACTH. Experimental work in rabbits substantiated their clinical observation that the hormone administered in large doses caused a retardation of appearance of all elements of connective tissue. Employing smaller dosages, they observed a delay in the appearance of granulation tissue rather than complete suppression of growth. Other investigators working along the same lines confirmed this depression of mesenchymal tissue activity with the administration of cortisone. Evidence of suppressed formation of peritoneal adhesions due to talcum powder by cortisone was first reported by Scheinberg and Saltzstein (10, 11). Similar findings have been reported by Odell, Key, and Taylor. Our interest has been stimulated to determine whether cortisone will prevent the formation of peritoneal adhesions following removal of the serosa of the small intestine in the dog. This more nearly simulates the human operative problem of controlling adhesions resulting from raw areas which cannot be reperitonealized.

In contrast to the agreement of findings of granulation tissue depression, observations of the effect of cortisone on wound healing itself are at variance. Some of these differences may be due to the experimental animal used; others may be due to differences in the dosages of hormone employed. Cole and his co-workers produced standard wounds in dogs and studied the effect of cortisone in wounds healing per primam. Under the conditions of their experiment, no difference was noted in the rate or quality of healing between cortisone-treated and control dogs, as determined by histologic examination of the wounds. No tensile strength studies were done in these animals.

Upton and Coon studied the effect of cortisone and ACTH in wound healing in normal and scorbutic guinea pigs. They concluded that ACTH and cortisone in doses sufficient to alter the adrenals and depress the circulating eosinophils failed to influence the repair of wounds in normal or scorbutic guinea pigs. Their criteria of healing were histologic details. Alrich, Carter, and Lehman reported delaying healing of abdominal wounds in albino rats treated with ACTH and cortisone by both histological and tensile strength studies. Baxter and associates studied the effect of ACTH in wound healing in man, with particular respect to skin grafts, and with the dosages employed failed to note any result other than certain side effects known to be harmful. Howes and co-workers demonstrated decreased tensile strength in wounds in cortisone-treated rats.

Shapiro and associates studied the local effect of cortisone on granulation tissue developing around turpentine abscesses and noted inhibition. In the same animal a simultaneous turpentine abscess treated without cortisone showed no such inhibition. Michael and Whorton noted delay of the early inflammatory response by cortisone in wounds in rabbits produced by croton oil and scarification; and Selye demonstrated decreased resistance to infection in the cortisone-treated rats.

METHOD

Series I. Ten mongrel dogs, weighing 6 to 10 kilograms, were used. Laparotomy was carried out under strict aseptic conditions, intravenous nembutal anesthesia being used in each instance, 30 milligrams per kilogram.

From the Departments of Surgery, Western Reserve University School of Medicine, and University Hospitals, Cleveland.

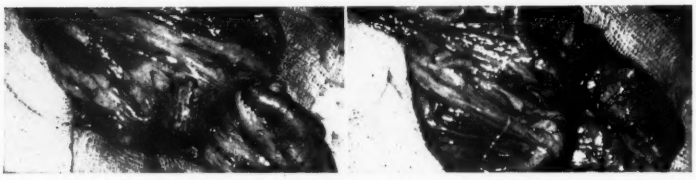

Fig. 1. Photograph of adhesions present in animals 9 and 10 at first relaparotomy at 13 days. Left, Animal 9 served as control. Right, Animal 10 received cortisone, 64 milligrams daily. Adhesions equal in character and extent.

Starting 15 centimeters distal to the ligament of Treitz, the serosa of 30 centimeters of jejunum was stripped with mosquito forceps along the antimesenteric border. The length of the segment was measured with a metal scale before manipulation, in an attempt to minimize variations due to changing tone of the bowel. The width of the area in each instance was measured at the completion of the serosal stripping and varied with the size of the bowel between 1.5 and 2.25 centimeters.

An equal number of dogs were operated upon each day to make conditions identical in the 5 control and the 5 experimental animals. The latter received 8 milligrams of cortisone per kilogram per day. This high dosage (60 to 85 milligrams per day per dog) by intramuscular injection was employed to give a maximum effect.

The first dose was given to each of the experimental animals at the close of the first laparotomy and continued, with 2 exceptions, as daily injections to the end of the experiment, 27 to 35 days later. The control animals did not receive cortisone, but were otherwise treated as those in the experimental group.

Three subsequent laparotomies were carried out on each animal. At each, the extent of the adhesions was observed and photographed (Figs. 1, 2, and 3). The adhesions were then broken down by sharp and blunt dissection and the area of raw surface measured in square centimeters. By this method we obtained 3 subsequent observations on the state of adhesions in each animal. Each laparotomy was carried out through a fresh wound isolating the previous incision to avoid contamination. No evidence of intraperitoneal infection occurred with the exception of the third laparotomy on animal I and the second laparotomy on animal II, and these were excluded from the series, making 14 control and 13 experimental observations.

At the close of the experiment, 3 of the control animals (III, VII, and IX) were given cortisone (70 to 85 mgm. per day) and subjected to relaparotomy at the end of another week. The cortisone was started immediately after operation in an effort to simulate the clinical problem of adhesion prevention following lysis of adhesions at laparotomy.

Two experimental animals (VIII and X) were sacrificed 1 week following the third laparotomy, during which time cortisone was not given, and the adhesions were measured.

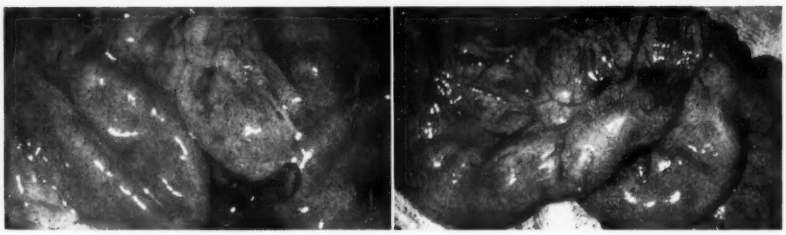

Fig. 2. Photograph of adhesions present in animals 5 and 6 at second relaparotomy at 22 days. Left, Animal 5 served as control. Right, Animal 6 received cortisone, 62 milligrams daily. Adhesions fewer and less dense in cortisone-treated animal.

Fig. 3. Photograph of adhesions present in animals 7 and 8 at third relaparotomy at 33 days. Left, Animal 7 served as control. Right, Animal 8 received cortisone, 64 milligrams daily. Note dense, matted adhesions in animal 7. Adhesions filmy and fewer in cortisone-treated animal.

Series II. Five mongrel dogs, weighing 6.3 to 16.5 kilograms were used. Cortisone, 8 milligrams per kilogram per day, was given for 9 days prior to laparotomy, following which identical procedures were carried out as in Series I. The administration of cortisone was continued postoperatively. On the eighth postoperative day, all 5 animals were subjected to relaparotomy, and the extent of the adhesions was measured and photographed.

RESULTS

Table I summarizes the results of 5 animals that did not receive cortisone. With successive laparotomies it may be seen that in only 1 animal was there a diminution of the area of raw surface. The averages for the 5 animals indicate a slight increase in raw surface area with each successive laparotomy. This observation is consistent with our clinical knowledge in human beings.

Table II summarizes the results of 5 animals that received 8 milligrams of cortisone per kilogram per day, starting on the day of operation. Here it is seen that only 1 animal showed an increase in raw surface area with successive laparotomies. There was a decrease in raw surface area with successive laparotomies in the other 4 animals. The average figures, in the lower line, show a diminution in raw surface area with successive laparotomies. In general, this effect was more marked at the third laparotomy when the animals had been receiving cortisone for the longest period. With the exception of 1 animal (II) the density of the adhesions was less in the cortisone-treated animals than in the corresponding controls.

Table III gives the results of 3 of the control animals that, following the third laparotomy, were placed on cortisone for a period of 1 week. It is noted that in none of the 3 animals did a significant decrease in raw surface area occur. The average raw surface area for the 3 animals actually increased slightly. If cortisone were to be useful clinically, it would seem to us that it would need to be effective under these circumstances.

Table IV gives the results in 2 of the cortisone-treated dogs sacrificed 1 week after the third laparotomy and the cessation of the cortisone administration. In both of these animals the area of adhesions was increased after

TABLE I.—AREA OF RAW SURFACE WITH SUCCESSIVE LAPAROTOMIES—CONTROLS

	Dog No.	Sq. cm. raw surface	Wt. kgm.	Sq. cm. relaparotomy 1, 7–13 days	Wt. kgm.	Sq. cm. relaparotomy 2, 19–26 days	Wt. kgm.	Sq. cm. relaparotomy 3, 27–33 days	Wt. kgm.
No cortisone	I	52		64		33			
	III	60	11.05	50	11.50	109	10.4	94	10.5
	V	52	8.7	52	8.2	59	8.0	64	7.8
	VII	45	5.95	37	5.8	58	5.75	66	5.8
	IX	52	9.0	60	8.6	73	9.3	52	8.75
Average		52	8.7	52	8.5	67	8.4	69	8.1
Per cent		100		100		128		132	

TABLE II.—AREA OF RAW SURFACE WITH SUCCESSIVE LAPAROTOMIES WITH CORTISONE

Dog No.	Mgm. cortisone per day	Sq.cm. raw surface	Wt. kgm.	Sq.cm. relaparotomy 1, 7–13 days	Wt. kgm.	Sq.cm. relaparotomy 2, 19–26days	Wt. kgm.	Sq.cm. relaparotomy 3, 27–33days	Wt. kgm.
II	85	60		84					
IV	85	45	10.4	67	10.4	58	9.75	29	9.5
VI	62	67	7.8	64	7.85	40	7.45	32	7.35
VIII	64	52	9.2	29	8.6	35	9.15	38	9.38
X	64	60	8.1	53	7.6	43	7.47	45	7.7
Average		59	8.8	59	8.6	44	8.5	36	8.2
Per cent		100		100		74		61	

TABLE III.—RESULTS IN 3 CONTROL ANIMALS GIVEN CORTISONE FOLLOWING THIRD LAPAROTOMY AND SACRIFICED 1 WEEK LATER

Dog No.	Mgm. cortisone per day	Sq. cm. raw surface control	Wt. kgm.	Sq. cm. raw surface after 1 week cortisone	Wt. kgm.
III	85	94	10.5	97	10.0
VII	80	66	5.8	109	5.75
IX	70	52	8.75	44	7.8
Average		70	8.35	81	7.85

TABLE IV.—RESULTS IN 2 CORTISONE-TREATED ANIMALS SACRIFICED 1 WEEK FOLLOWING THIRD RELAPAROTOMY AND WITHDRAWAL OF CORTISONE

Dog No.	Sq. cm. raw surface control	Wt. kgm.	Sq. cm. raw surface	Wt. kgm.
VIII	38	9.38	78	9.0
X	45	7.7	73	7.1
Average	41		75	

Last dose of cortisone 24 hours before third relaparotomy.

laparotomy and the omission of cortisone. The dogs had received their last cortisone injection 24 hours before the third laparotomy, indicating that any adhesion-preventing effect was lost very soon after the cessation of cortisone administration.

Table V summarizes the findings in 5 animals in series II, in which cortisone was administered for 6 days prior to the first laparotomy and was continued to the day of relaparotomy. In 2 animals, XIII and XIV, a significant decrease in raw surface area occurred, while in the other 3 there was only slight diminution. There was some overall effect on the character of the adhesions in that in this group they were not so dense as in the control animals of series I.

DISCUSSION

Relaparotomy in control animals that received no cortisone caused either an increase in the area of adhesions or no change. This is consistent with clinical experience in patients in whom relaparotomy usually leads to an increase in peritoneal adhesions.

Relaparotomy and the administration of cortisone in large dosage intramuscularly gave a moderate decrease in the area of adhesions in most of the dogs, along with a diminution in the density of the adhesions. Under the conditions of this experiment, in no instance were adhesions completely prevented by cortisone.

If one compares the area of raw surface shown in Table II, it is seen that the effect of cortisone was increased with prolonged administration. Similar results were obtained in series II, where the animals were pretreated with cortisone. There was little effect when the drug was started following laparotomy, except in animal VIII and the last laparotomy on animal IX.

Furthermore, in 2 instances the effect of the cortisone was lost when the drug was discontinued 24 hours before laparotomy in animals VIII and X.

Observations on wound healing in series I are summarized in Table VI. Since all wounds in these animals were abdominal, it was impossible to use any type of dressing which was completely satisfactory, and therefore no covering was employed. In general, the control animals' wounds healed primarily with only occasional stitch abscesses. In 1 control animal (III) at the third relaparotomy, a 2 inch healthy granulating wound was observed. Its cortisone-treated counterpart, animal IV, had a partial dehiscence in the rectus muscle with complete absence of granulations. The cortisone-treated animals developed a higher incidence of wound complications, some of which may have been due to metabolic side effects.

Cole and co-workers, producing wounds over the scapulae in dogs to minimize the possibility of contamination, noted no difference in the quality of wound healing in the control of cortisone-treated dogs (2 mgm. per kgm. per day). Scheinberg, Saltzstein, and Johnson observed primary healing of wounds in approximately 500 animals, both control and cortisone-treated. Hench and co-workers reported no alteration in primary wound healing in several patients receiving ACTH or cortisone or both, who had undergone arthrotomies and needle biopsy. Thorn and co-workers and Cole reported similar experience in patients.

The differences between adhesions produced by talc and denudation of loops of in-

TABLE V.—AREA OF RAW SURFACE FOLLOWING STANDARD PROCEDURE IN ANIMALS PRETREATED WITH CORTISONE

Dog No.	Mgm. cortisone per day	Sq. cm. raw surface	Wt. kgm.	Sq. cm. raw surface at relaparotomy 8 days later	Wt. kgm.	Wound healing
XI	52	45	6.5	37	6.3	Moderate stitch infection
XII	50	45	6.3	43	6.6	Primary
XIII	90	68	11.2	21	10.2	Moderate stitch infection
XIV	132	60	16.5	24	15.0	Moderate stitch infection
XV	90	51	11.3	44	10.2	Mild stitch infection
Average		53	10.3	34	9.5	

stine may be reconciled to some extent by the experimental evidence at hand. Since talcum powder produces a marked granulomatous inflammatory response, the mode of action here of cortisone may be due to a depression of factors in the inflammatory phase of granuloma formation. With the denudation of bowel, although mesothelial regeneration is rapid, fibrinous agglutination of the surfaces promotes fibrous adhesions. In our opinion, this type of healing is more akin to primary wound healing, and it is in this phase that cortisone has very little effect. Although in the data presented, there was diminution in the area of adhesions produced, this phenomenon occurred only after prolonged administration of cortisone in large dosage and may be related to other factors known to be detrimental to wound healing. The metabolic demands in the animal to heal a wound by secondary intention are greater than in wounds healing per primam, and disturbances produced by the administration of adrenal cortical steroids apparently exert a greater quantitative effect on the secondary or inflammatory wound.

SUMMARY

An attempt has been made to evaluate the effect of cortisone in large dosage on the formation of adhesions secondary to denuded areas of jejunum in the dog. The average raw surface area from denuded jejunum increased in 5 control animals with successive relaparotomies to 132 per cent of the initial area at the time of the third relaparotomy. The average raw surface areas of the cortisone-treated animals in series I and II were not reduced unless the animals were receiving cortisone preoperatively and it was continued after operation. The administration of cortisone, postoperatively only, was not effective in reducing raw surface area except in animals VIII and X (Table II) and animal IX (Table III). The effect was lost in 2 animals when cortisone was discontinued 24 hours before relaparotomy (Table IV).

TABLE VI.—SUMMARY OF WOUND HEALING OF ANIMALS IN SERIES I

Dog No.	Relaparotomy 1	Relaparotomy 2	Relaparotomy 3	Relaparotomy 4
No cortisone				
I	Primary	Primary	Subcutaneous infection	
III	Primary	Primary	Healthy granulating wound—2″	Primary*
V	Stitch infection	Primary	Stitch abscess slight	
VII	Primary	Primary	Primary	Primary
IX	Primary	Incompletely healed	Stitch infection	Serum*
Cortisone				
II	Primary	Primary	Small intraperitoneal abscess	
IV	Primary	Serum, partial dehiscence	Dehiscence to muscle, no granulation	
VI	Slight separation of edges	Primary	Stitch abscess, slight	
VIII	Serum, stitch abscess	Primary	Primary	Inflamed, incompletely healed**
X	Primary	Primary	Stitch infection	Dehiscence to fascia†

*Cortisone added
†Cortisone withdrawn

CONCLUSIONS

1. Under the conditions of this experiment when cortisone was administered immediately postoperatively, the production of peritoneal adhesions by serosal denudation of jejunum was not inhibited when compared with control animals.

2. Although some inhibition of adhesions was noted when the dogs received the drug preoperatively as well as postoperatively, it occurred only after prolonged high dosage.

3. Cortisone did not completely prevent adhesions in any animal, though the adhe-

sions were, in general, less extensive and less dense.

4. An attempt has been made to correlate the differences between the primary and secondary wound with the administration of cortisone.

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PREINVASIVE CARCINOMA OF THE CERVIX DURING PREGNANCY

R. R. GREENE, M.S., M.D., BEN M. PECKHAM, Ph.D., M.D., J. T. CHUNG, M.S., M.D., M. A. BAYLY, M.D., H. B. W. BENARON, M.D., LEON A. CARROW, M.D., and G. H. GARDNER, M.D., F.A.C.S., Chicago, Illinois

IT is almost universally accepted that pregnancy causes specific changes in the epithelia of the cervix (i.e. both endocervical glandular epithelium and ectocervical stratified squamous epithelium). It is almost as widely believed that "changes" may occur that are confusable with preinvasive carcinoma of the cervix. Because of this, many believe that the diagnosis of preinvasive carcinoma of the cervix cannot and should not be made in the pregnant patient. This latter belief has most frequently been expressed in the published discussions following papers concerning the cervix during pregnancy. However, Epperson and co-workers reported that 5 lesions diagnosed as preinvasive carcinoma of the cervix during pregnancy disappeared spontaneously at the termination of pregnancy. The inference, of course, was that these were "pregnancy changes" and not true preinvasive carcinoma. More recently, Nesbitt and Hellman have reported a continuation of the work of Epperson and his associates. They found 2 more such lesions that also disappeared after cessation of the pregnancy.

A few individuals (including the present authors) do not believe that pregnancy causes *specific* changes in the cervical epithelia. They grant that metaplasias and hyperplasias of glandular elements are more common and more prominent during pregnancy than in the nonpregnant state. These changes, however, are not peculiar to pregnancy. They also grant that the surface stratified squamous epithelium of the cervix grows rapidly during pregnancy and a mild increase in the thickness of the basal cell layer with normal nuclei is occasionally seen. They also believe that when the criteria are present for the diagnosis of preinvasive carcinoma, that diagnosis should be made irrespective of whether the patient is or is not pregnant. The detailed literature on these subjects has been presented by Carrow and Greene and by Nesbitt and Hellman. It will not be repeated here.

This controversy (preinvasive carcinoma in pregnant patients) can only be settled by deliberately following patients with such lesions and determining whether these lesions do or do not disappear with the termination of pregnancy. The data that follow have been obtained from exactly such a co-operative study. This material is part of a larger study concerned with the cervix during pregnancy and the postpartum period. Most of the patients involved are from the Chicago Maternity Center, where approximately 90 per cent of them are colored. One patient included here was a private patient of one of the authors. Two others are service patients from other institutions in Chicago (one from Northwestern University Medical School Clinics and one from St. Lukes Hospital).

It is believed that good photographs are more convincing than many paragraphs of description. Therefore the text will be kept at a minimum and photographs will be presented of the lesions during pregnancy and during the postpartum period. Detailed findings on the patients are presented in Table I. As will be noted, the time that the biopsies or smears were taken is given in regard to weeks of pregnancy or weeks postpartum. As may also be noted, the number of times a patient was biopsied and whether the biopsies were single, 2, or 4 quadrant specimens are listed. We believe that this latter point is important. Some

From the Department of Obstetrics and Gynecology, Northwestern University Medical School and of Wesley Memorial Hospital, and from the Chicago Maternity Center.

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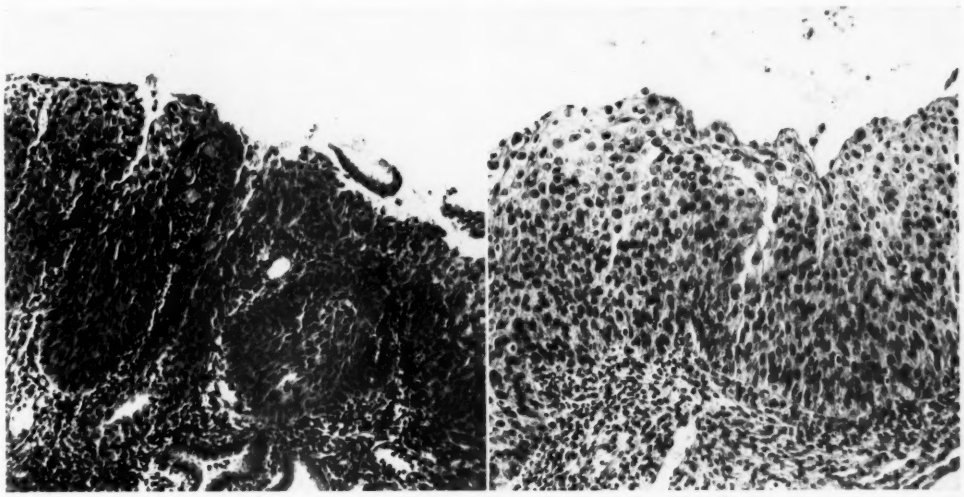
TABLE I.—CARCINOMAS OF THE CERVIX IN PREGNANCY AND POSTPARTUM

Patient No. Name	Date[1]	Age, years[2] Grav. Para	Antepartum			Postpartum				Comments
			Weeks	Smear	Biopsy	Weeks	Smear	Biopsy	Hyst or cone	
1 S.B.	Sept. 1949	23 G 1 P 1	37		(1) Ca	15 20	Pos	(3) Ca	BCH(hyst)	
2 R.H.	Jan. 1951	28 G 7 P 7	15 20 24 26	Uns Neg 	(2) Ca (1) Neg (1) Neg	6 6 mo 12 mo	Atyp Neg Neg	(4) Neg (4) Neg		
3 K.J.	Jan. 1952	21 G 1 P 1	33 36 39	Atyp Atyp Atyp	 (3) Ca (1) Ca	7 26	Atyp	(4) Ca (4) Neg		Cervix cauterized 16 wks postpartum by private M.D.
4 T.K.	May 1951	30 G 1 P 1	10 13 14 27	Atyp Atyp Atyp Pos	 (1) Ca (4) Ca	5 10 16	Pos Pos Atyp	(4) Ca	Ca (cone)	
5 A.L.	March 1951	23 G 7 P 7	31	Atyp	(1) Ca	17 31	Pos Neg	(4) Neg (4) Neg		Since completed 8th pregnancy
6 F.P.	Sept. 1947	23 G 7 P 7	24 25 26 28 38 39		(1) Ca (1) Ca (1) Ca (1) Neg (1) Ca (1) Neg	Del 3 9 22 12 mo 27 mo 28 mo 29 mo	 Atyp Pos	(1) Ca (1) Ca (1) Ca (1) Neg (1) Neg (4) Ca	Ca (hyst)	Hysterectomy done 2 years and 7 months after first biopsy
7 M.R.	March 1951	22 G 2 P 2	16 21 27	Atyp Atyp Atyp	 (2) Ca	Del 9 11	 Atyp	(1) Neg (4) Ca*	Ca (hyst)	Biopsy at delivery—large condyloma acuminata
8 N.R.	March 1950	25 G 4 P 3	28		(4) Ca	8 15		(4) Neg	Ca (cone)	Biopsy at 8 wks. postpartum uns. (No squamo-columnar junction)
9 H.R.	Oct. 1951	31 G 5 P 2	16–18 18–20	Atyp	(1) Ca (4) Ca	6 11		(4) Ca	Ca (hyst)	
10 M.S.	Jan. 1950	19 G 3 P 3	24 25	Pos	(1) Ca (4) Ca	1 7	Pos	(1) Ca	Ca (hyst)	This patient was mentioned in a previous communication (1) at that time undelivered
11 L.S.	Nov. 1949	26 G 5 P 3	28 32 33	Atyp Neg	 (1) Ca (3) Neg	8	Neg	(4) Ca*		First pregnancy
			27–29		(1) Ca	4 9 14	Atyp Atyp	(4) Ca	Ca* (hyst)	Second pregnancy
12 G.T.	May 1951	22 G 2 P 2	3 5 26	Atyp Atyp	 (4) Ca* (4) Ca	8 11	Pos	(4) Ca		The cone amputation was done on the 5th week of an unrecognized pregnancy which is progressing normally
			5						Ca (cone)	
13 R.W.	June 1951	23 G 1 P 1	5 6	Pos Pos	(4) Ca	19	Pos	(4) Ca		Premature labor in 1st pregnancy. Cone amputation in 6th week of pregnancy at patients insistence. Abortion 4 weeks later
			6						Ca* (cone)	
14 D.W.	June 1951	23 G 1 P 1	16–18 22–24	Pos	(1) Ca (4) Ca	9 21	Pos	(4) Ca	(Ca hyst)	First biopsy at base of condyloma acuminata. Minimal invasion in hysterectomy specimen

Atyp—atypical; Pos—positive; Neg—negative; Uns—unsatisfactory; BCH—basal cell hyperplasia; Del—delivery; Hyst—hysterectomy; Ca—carcinoma (preinvasive unless otherwise specified); Ca*—Equivocal carcinoma. The numbers in parentheses refer to the number of quadrants biopsied.

[1]Month and year of first smear or biopsy.

[2]Age at first smear or biopsy; gravity and parity after last pregnancy unless otherwise noted.



a b

Fig. 1.

Fig. 1. a, Patient 1, NUMS 11952. Antepartum biopsy, 36 to 38 weeks pregnant. There is extension into glands in this field. Magnification, ×117. b, Patient 1, NUMS 12434. Postpartum biopsy, 15 weeks. As in the antepartum specimen, there is some maturing of the cells as they near the surface but the nuclear abnormalities persist. Magnification, ×117.

Fig. 2. Patient 2, NUMS 14009. Antepartum biopsy, 15 weeks pregnant. Minute area of poorly differentiated carcinoma with extension into glands as shown in this field. This lesion was not found postpartum. Magnification, ×85.

Fig. 2.

of these lesions are quite small. Single biopsies can be taken several times during the postpartum period and still one may miss a lesion that has persisted after the termination of pregnancy.

Some of these lesions were chance findings in biopsies made for the study of the pregnant and postpartum cervix. Others were discovered in biopsies made because of a preceding atypical or suspicious Papanicolaou smear. If the diagnosis was made during pregnancy from a single biopsy, an attempt was made to obtain 4 quadrant biopsies which were thoroughly studied before a final decision was reached whether or not the patient could be followed through pregnancy with safety. In a

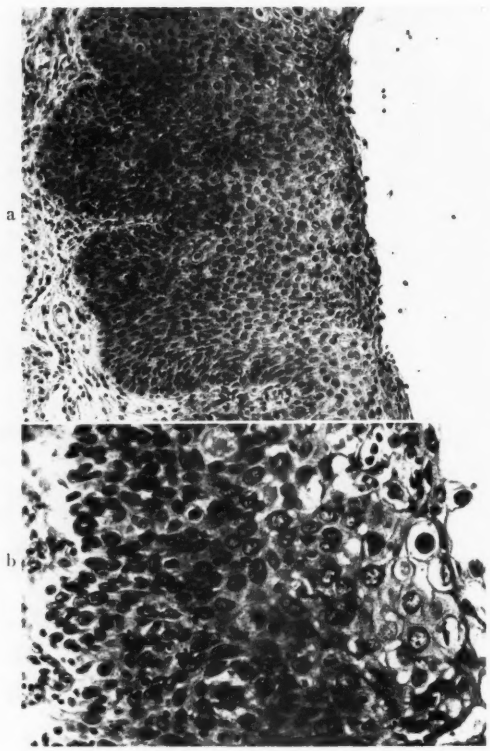


Fig. 3.

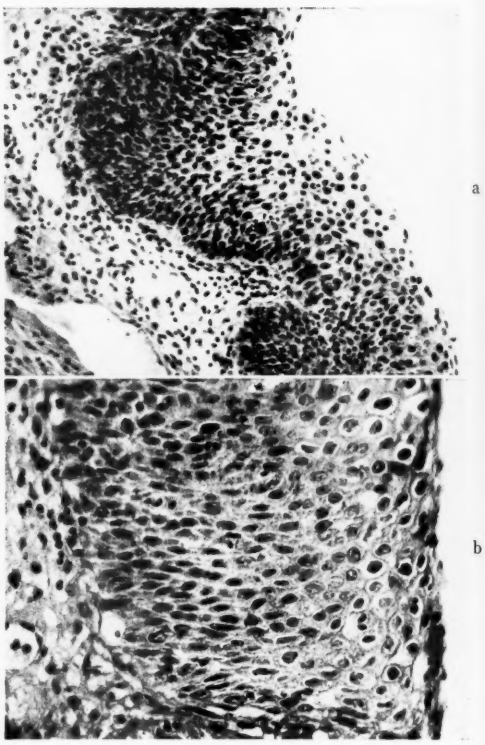


Fig. 4.

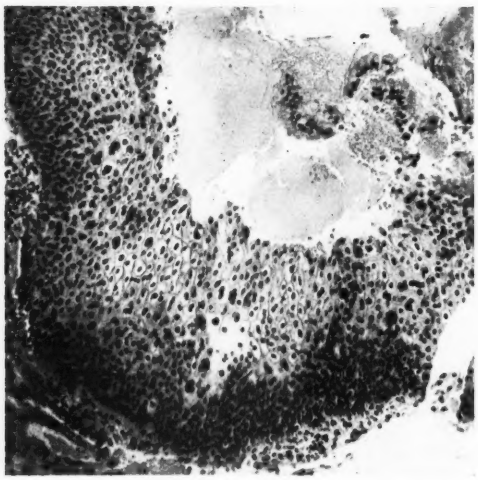
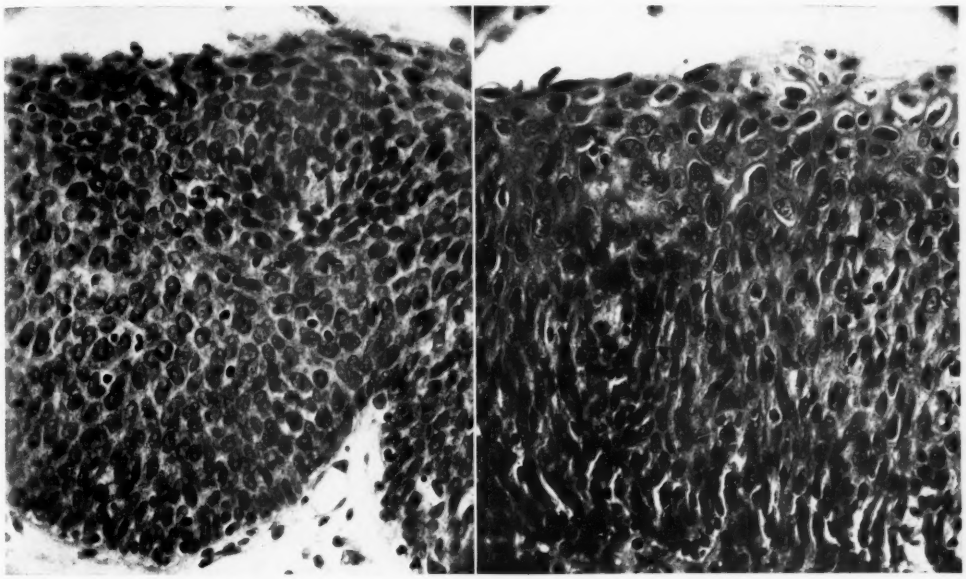


Fig. 5.

Fig. 3. a, Patient 3, NUMS 16152. This antepartum lesion (39 weeks pregnant) shows moderate differentiation. Magnification, ×113. b, Patient 3, NUMS 16568. From the first postpartum biopsy (7 weeks). The lesion is similar except the cells are more differentiated as they near the surface. Magnification, ×274.

Fig. 4 a, Patient 4, NUMS 14845. From an antepartum biopsy, 14 weeks pregnant. Fairly well differentiated in this area; less differentiated in other areas. Magnification, ×113. b, Patient 4, NUMS 16544. From the 16 weeks postpartum operative specimen. Little differentiation in this field, more so in others. Magnification, ×274.

Fig. 5. Patient 5, NUMS 14368. Antepartum biopsy, 31 weeks pregnant. Well differentiated lesion in single antepartum biopsy. No lesion was found postpartum. Magnification, ×104.



a b

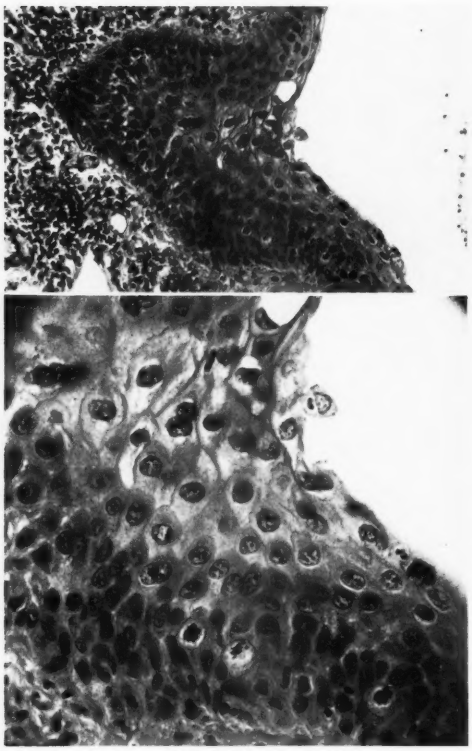
Fig. 6. a, Patient 6, 1948 Cl 8. Antepartum biopsy (38 weeks pregnant) of poorly differentiated lesion. Magnification, ×311. b, Patient 6, NUMS 12875. Postpartum biopsy. The lesion was found in this biopsy 28 months postpartum, as well as in the operative specimen. Magnification, ×311.

few of the cases presented here (which date back several years) this procedure obviously was not followed.

Only the 14 patients with lesions considered to be definite preinvasive carcinoma during pregnancy will be considered here. An additional group of patients with equivocal or questionable carcinoma or marked basal cell hyperplasia with nuclear atypia will be the subject of another article to be published subsequently.

The criteria for the diagnosis of preinvasive carcinoma of the cervix must, unfortunately, be considered in slight detail. The following remarks pertain, of course, only if one will grant that the diagnosis of preinvasive carcinoma of the cervix is ever valid. It is universally agreed that the changes or abnormalities (almost exclusively nuclear) must exist through all the layers of the epithelium. Some individuals in addition, consciously or unconsciously, demand a uniformity in appearance throughout all the thickness of the epithelium before they agree that a diagnosis of preinvasive carcinoma of the cervix is justified. In the absence of this relative uniformity, they will make a diagnosis such as "anaplasia" or, in some instances, basal cell hyperactivity. In most instances, undoubtedly, this attitude is justified. However, in our opinion such an attitude occasionally, at least, makes impossible the diagnosis of *well differentiated*, preinvasive squamous cell carcinoma of the cervix. Certainly in this latter condition cells may mature as they near the surface and in so doing gain more cytoplasm and thus the nuclei are no longer as closely packed as they may be in the lower or lowermost layers. In such instances we believe that the diagnosis of well differentiated carcinoma is justified. May we please call attention to the fact, however, that although the cells tend to mature as they near the surface, they do not become normal in appearance. The nuclei are still large and hyperchromatic and very frequently the nucleoli are unusually large and multiple.

An attempt has been made to pick photographic fields that were characteristic of the



a

b

Fig. 7. a, Upper, Patient 7, NUMS 14664. Moderately well differentiated lesion in the 27th week of pregnancy. Magnification, ×113. Lower, Higher magnification of same area. Note mitotic figures and multinucleated cells. Magnification, ×274. b, Patient 7, NUMS 15560. Area from hysterectomy specimen (11 weeks postpartum). In another field there is questionable tissue invasion. Magnification, ×113.

lesion. As is obvious to anyone who has studied similar material, this is frequently extremely difficult. Occasionally such lesions will vary in differentiation or "grade" from one area to another. A particularly impressive area may be impossible to photograph because the tissue is not flat.

In a few instances the reader may not believe the findings sufficient to justify the diagnosis of carcinoma. It is quite possible that such is the case. The important point, however, and the major point in this paper is that, with 2 exceptions, *these lesions whether they were true carcinoma or not, were not "pregnancy changes" and did not disappear but persisted after termination of the pregnancy.* In 2 of the 14 instances (Patients 2 and 5) we have been unable to find any abnormality postpartum. The burden of proof always remains on the individual who claims that a lesion was completely removed in the biopsy or destroyed by inflammatory changes and for this reason was not found again. We make no such claims. It is possible that the lesion was not a true preinvasive carcinoma and that it was a reversible change. Incidentally, 4 quadrant biopsies have been done twice postpartum on each of these patients and they are to be followed further. In 1 of these (Patient 5) the smear was positive at the time of the first postpartum biopsy (17 weeks) but negative at 31 weeks.

In 1 instance (Patient 6) the findings in the postpartum biopsies at 9 weeks were considered to be "equivocal" or not quite sufficient to justify the diagnosis of carcinoma. Definite carcinoma was found in the hysterectomy specimen at 11 weeks. In another patient (Patient 1) the findings were definite in the biopsies at 15 weeks postpartum. In the

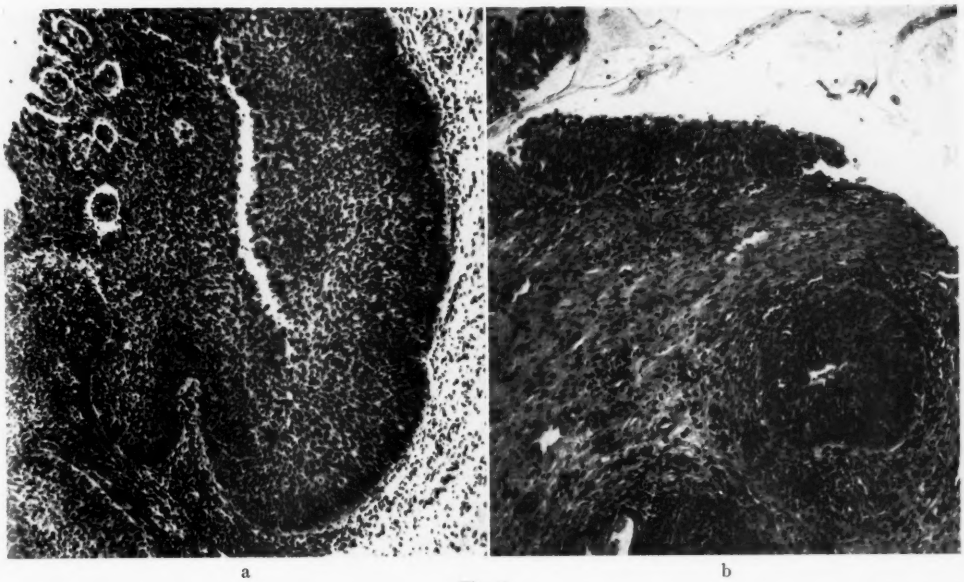


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Fig. 8.

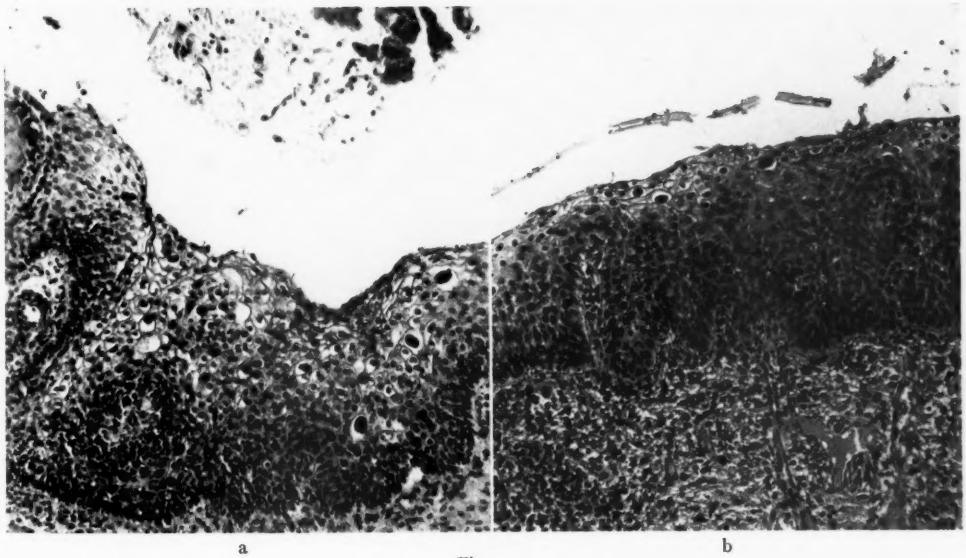

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Fig. 9.

Fig. 8. a, Patient 8, NUMS 12856. Antepartum biopsy (28 weeks pregnant) showing poorly differentiated lesion. Magnification, ×68. b, Patient 8, NUMS 13590. From operative specimen, 14 weeks postpartum. The lesion is similar and in this field has extended into a gland. Magnification, ×78.

Fig. 9. a, Patient 9, NUMS 15430. From antepartum biopsy (16 to 18 weeks pregnant) showing a well differentiated lesion. Magnification, ×117. b, Patient 9, NUMS 16513. From the hysterectomy specimen, 6 weeks postpartum. The lesion is identical to that of the antepartum period. Magnification, ×117.

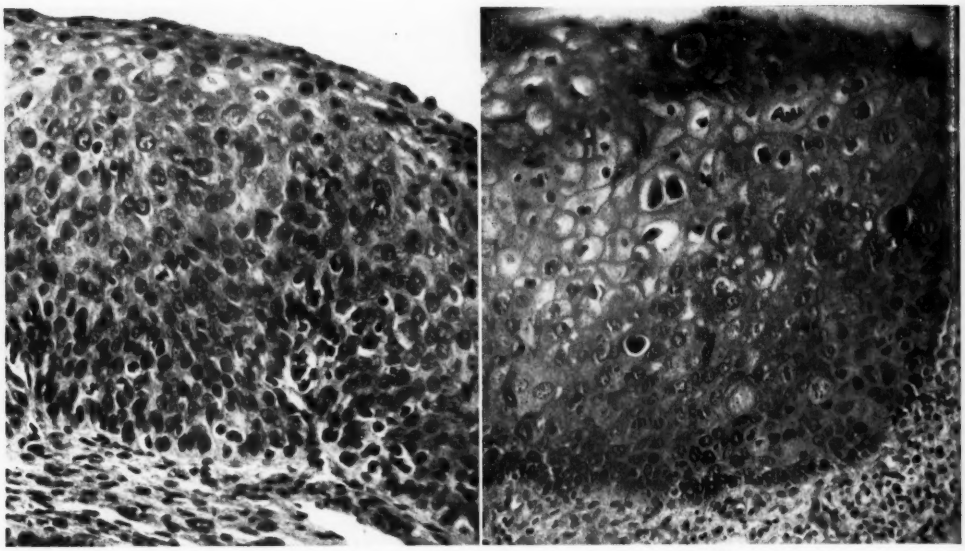

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Fig. 10.

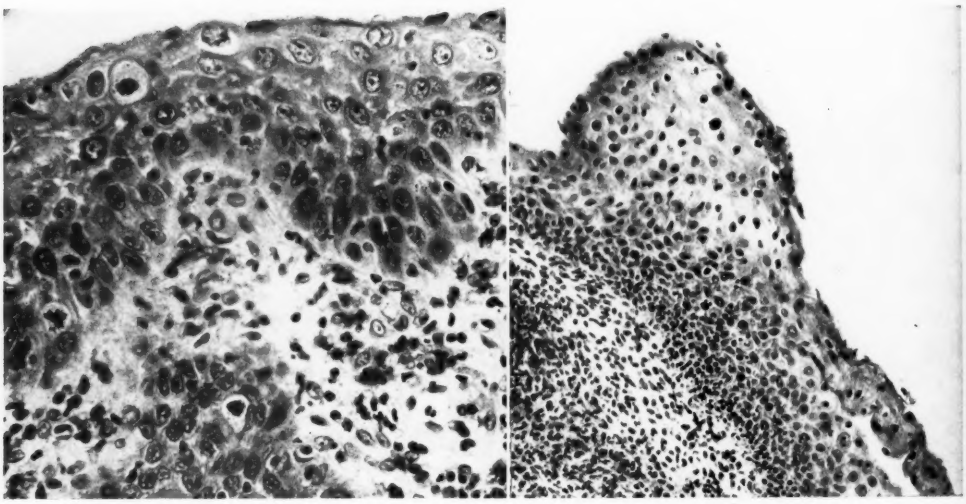

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Fig. 11.

Fig. 10, a, Patient 10, NUMS 12432. Antepartum biopsy, 25 weeks pregnant. Other areas show a higher degree of differentiation. Magnification, ×282. b, Patient 10, NUMS 12860. Hysterectomy specimen at 7 weeks postpartum. Tissue preparation of poor quality. Shows higher degree of differentiation than in Figure 10a. Magnification, ×282.

Fig. 11. a, Patient 11, NUMS 13760. Lesion during the second pregnancy at 27 to 29 weeks. The malignant epithelium near the bottom is glandular extension and not tissue invasion. Magnification, ×311. b, Patient 11, NUMS 14370. From biopsy after end of second pregnancy, 9 weeks postpartum. The mound-like elevation is due to tangential plane of section. Magnification, ×117.

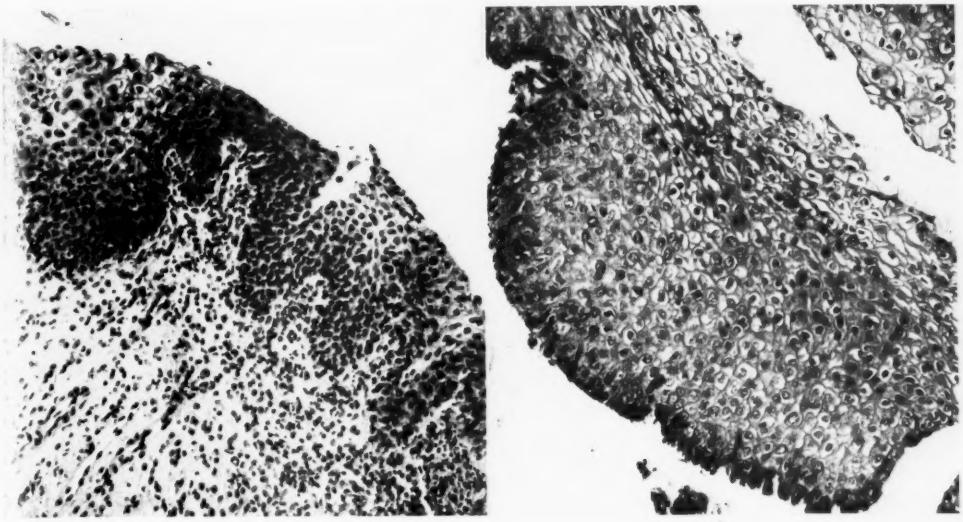

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Fig. 12.

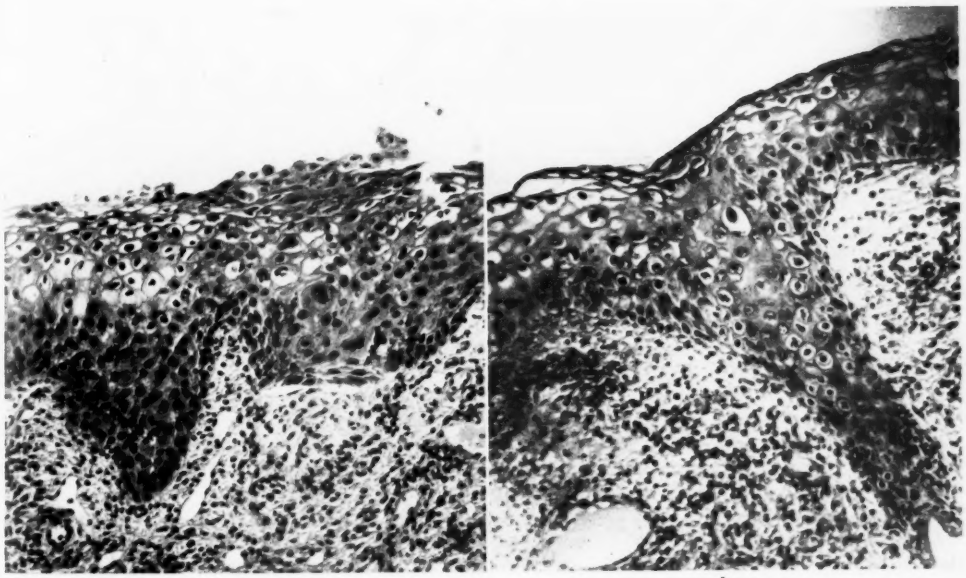

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Fig. 13.

Fig. 12. a, Patient 12, NUMS 15518. A moderately well differentiated lesion from the 26th week of pregnancy. Magnification, ×117. b, Patient 12, NUMS 16301. From the 11th week postpartum biopsies. The lesion is similar although perhaps slightly more differentiated than in a. Magnification, ×117.

Fig. 13. a, Patient 13, NUMS 15382. A well differentiated lesion in the antepartum biopsy (6 weeks pregnant). Mitotic figures are extremely numerous. Magnification, ×117. b, Patient 13, NUMS 16877. An identical lesion in the 19th week postpartum biopsy with a similar profusion of mitotic figures. Magnification, ×126.

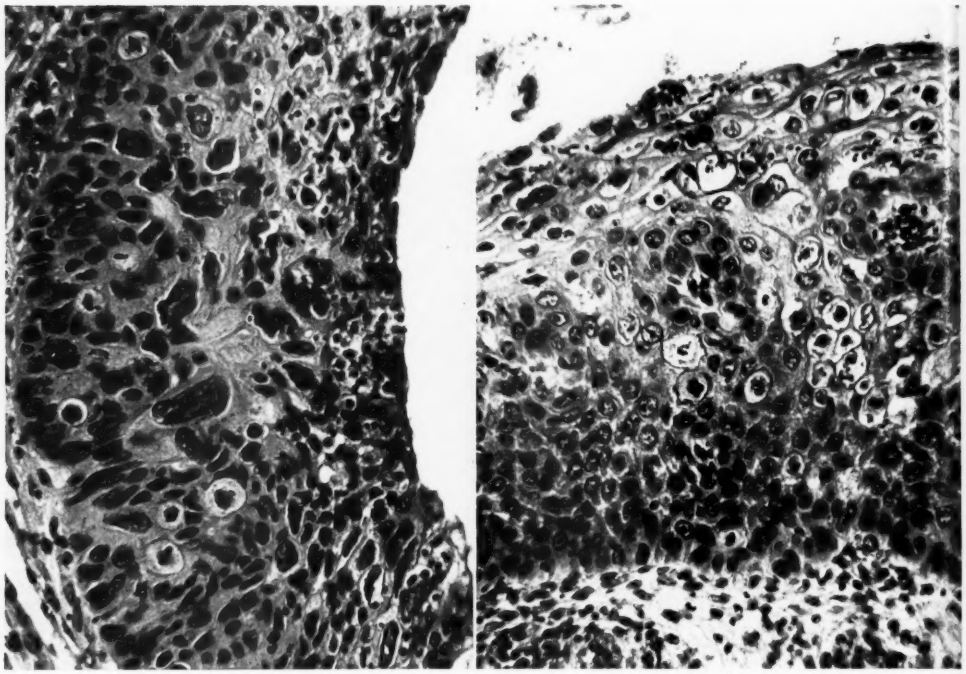

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Fig. 14. a, Patient 14, NUMS 14836. Antepartum biopsy, 20 weeks pregnant. Note the marked nuclear pleomorphism and profusion of mitotic figures. Magnification, ×311. b, Patient 14, NUMS 15866. In this 9th week postpartum biopsy the degree of differentiation is similar although there is less pleomorphism. Mitotic figures are even more abundant. There is early tissue invasion in the hysterectomy specimen. Magnification, ×311.

hysterectomy specimen at 20 weeks only basal cell hyperplasia with marked nuclear atypia was found. Patient 10 was followed through 2 pregnancies. After the first pregnancy the findings were considered to be equivocal. After the second pregnancy the findings were definite in the biopsies but equivocal in the hysterectomy specimen. Another patient (Patient 13) had definite findings 11 weeks postpartum. A cone amputation was done at 6 weeks in her next pregnancy. In this specimen the findings were considered to be equivocal. We do not know that the pregnancy caused the abnormalities to be less impressive but we are certain that the reverse is not true.

Our intention was to allow a fairly long period to intervene between delivery and hysterectomy or cone amputation of the cervix. This attitude was an attempt to obviate any possible confusion with "anaplasia" of healing of the cervix which had been traumatized by labor. Incidentally, in a study of cervical biopsies from another group of postpartum patients, we have noted no such anaplastic changes. A hysterectomy was done at 7 weeks in 1 patient, and at 11 weeks in 2 others. In the remaining patients the time varied from 4 months to 29 months.

As will be noted in the table, cone amputations of the cervix were done on several of the younger patients. The specimens were serially blocked (as were those from hysterectomy specimens). In no instance did the carcinoma extend lateral to or above the level of the amputation. This procedure is not recommended as adequate treatment of preinvasive carcinoma of the cervix in general. Our few indications for this therapy are not pertinent here.

It is extremely difficult to reconcile our findings with the generally accepted beliefs on this

subject and with the few specific reports implying that such lesions are evanescent pregnancy changes. Perhaps it has to do with the adequacy of the follow-up biopsies. We know from experience that follow-up may be difficult. The biopsies should be taken from 4 quadrants and should include the squamocolumnar junction. Well trained tissue technicians are all important in the proper orientation of the tissue in the blocks and the preparation of the sections for examination.

SUMMARY AND CONCLUSIONS

A diagnosis of preinvasive carcinoma of the cervix has been made on biopsies from 14 pregnant patients. These patients have been followed through pregnancy and the puerperium. The lesion persisted after the termination of pregnancy in 12 of the 14 patients and was found in the biopsies and/or operative specimens. *These lesions are therefore not pregnancy changes.*

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ABDOMINAL AORTIC ANEURYSM

Report of a Case Treated with Reactive Cellophane

WALTER R. WILKINSON, M.D., F.A.C.S., Huntington, West Virginia

OSLER gives credit to Vesalius for the first description in 1567 of an abdominal aneurysm. The first surgical attempt at correction of this condition was performed by Sir Astley Cooper, who ligated the abdominal aorta in 1817. From that time until 1920, none of the 18 patients in whom the aorta was occluded for aneurysm survived to leave the hospital.

In 1946 de Takats and Reynolds (3) stated that more than 500 cases of abdominal aortic aneurysm had been reported; of these, only 30 patients received surgical treatment, 6 surviving by more than 1 year. Since then, many attempts at definitive surgery probably have been made, but few reported. The purpose of this paper is to add 1 case of a surgically treated abdominal aortic aneurysm to the literature.

INCIDENCE

In 1950 Estes reported 102 cases of abdominal aortic aneurysms seen at the Mayo Clinic up to and including 1937. Saleeby and McCarthy reported 14 abdominal aortic aneurysms from a total of 74,629 surgical patients at Philadelphia General Hospital over a 32 year period. Feldman reports an incidence of about 0.035 per cent in hospital records with abdominal aortic aneurysm constituting 11.8 per cent of all aneurysms.

Abdominal aortic aneurysms may be of the fusiform, saccular, or dissecting variety and usually occur in that order of frequency. They develop secondary to arteriosclerosis, syphilis, or trauma. It was formerly thought that syphilis was the most common, if not the only cause of aortic aneurysm.

These aneurysms are more frequent in negroes which fact has been attributable to the prevalence of syphilis in that race. More recently, however, arteriosclerosis has been reported as the most frequent cause. Syphilitic aneurysms are certainly more common than arteriosclerotic aneurysms in people under 45 years and less frequent in the older age group.

The essential factors in the development of spontaneous aortic aneurysms are degeneration of the aortic wall, especially the media, and continuous or intermittent elevation of blood pressure.

Syphilitic aortic aneurysms are caused by syphilitic mesaortitis with destruction of the elastic tissue and are more common in the thoracic aorta, especially the arch.

Arteriosclerotic aneurysms are secondary to subintimal atheromatous degeneration and are most likely to be the fusiform type and involve the abdominal aorta. Aortic aneurysms are 7 to 10 times more common in the thorax than in the abdomen.

DIAGNOSIS

The symptoms of abdominal aortic aneurysm are variable and confusing. In about 30 per cent there are no symptoms referable to the aneurysm. The most common complaints, however, are abdominal pain, low back pain, and a pulsating mass located in the abdomen. These aneurysms occasionally masquerade as primary urologic or orthopedic disease. The most important physical signs of abdominal aortic aneurysms are an expansile, pulsatile abdominal mass which is seen in 50 to 80 per cent of cases and a thrill or bruit which is heard in 20 to 30 per cent of cases. Roentgen visualization of calcification in the aortic wall, and aortograms are definite aids, but regardless of all other diagnostic criteria, an expansile, pulsatile mass must be palpated before the antemortem diagnosis of aneurysm can be made.

TREATMENT

Judging from the paucity of reports of the surgical treatment of abdominal aortic aneu-

From the Surgical Service, Chesapeake and Ohio Hospital, Huntington, West Virginia.

rysms, only a few surgeons have felt that surgery is justifiable.

In 1940 Bigger and Elkin gave a complete tabulation on all cases operated upon until that time. Only 6 patients survived the surgical treatment for more than 1 year. These 6 patients were treated by proximal occlusion or partial occlusion of the aorta with cotton tape or fascia lata. Since then Estes has reported a case of partial ligation of the aneurysm with fascia lata. This patient died 4 years later of myocardial infarction.

Wiring of abdominal aneurysms has been done, but this method of treatment has been discouraging.

Endoaneurysmorrhaphy has been performed 3 times with success in but 1 instance. In that case Bigger performed an endoaneurysmorrhaphy upon a patient with a traumatic abdominal aortic aneurysm 1 month after partial occlusion with fascial lata.

More recently, reactive cellophane has been used but the number of reported cases has been small. In 1 case reported from the Mayo Clinic the aneurysm was wrapped with cellophane (5). Three years later he committed suicide because of severe pain. In 1946 de Takats reported 3 cases treated with cellophane: Case 1: A collar of cellophane was placed around the proximal aorta. The aneurysm became smaller. The patient refused a second operation for complete occlusion over the cellophane bands. He died from internal hemorrhage 14 months following surgery. Case 2: Cellophane wrapped around the aorta proximal to the aneurysm and an atheromatous plaque was covered with cellophane. The patient was living 14 months following surgery and was working without pain. The cellophane created a hard turret-shaped mass over the aneurysm. Case 3: Cellophane wrapped around the aorta proximal to the aneurysm. The patient died 1 year later because of bronchopneumonia and heart disease.

Of de Takats's (2) 10 patients with abdominal aortic aneurysms who received surgical treatment and were followed for approximately 5 years, 6 are dead and 4 are alive. As he points out, however, death is not always due to rupture of the aneurysm, but to a cardiovascular accident elsewhere.

REPORT OF CASE

L. S., 67 year old, white, conductor, was admitted to the Chesapeake and Ohio Railway Hospital on January 22, 1951. He gave a history of having been reasonably well until 2 months prior to admission, at which time he developed sore throat, coryza and nasal discharge which was followed by bronchitis. At the time of admission to the hospital, he complained chiefly of arthritis of 6 to 7 years' duration with the most severe symptoms in left shoulder and low back, but involving at different intervals most of the other joints as well. He had vague left upper quadrant discomfort with questionable relationship to the ingestion of food. He had no nausea, vomiting, or lower abdominal pain. He complained of abdominal gas and mild constipation. After a full day's work he was aware of a pounding sensation in the middle and lower abdomen which he described as feeling like a "trip hammer."

Nocturia 2 to 4 times with occasional episodes of mild dysuria were the only urinary complaints.

Physical examination revealed a well developed, well nourished male, in no acute distress. Blood pressure was 135/75, pulse 75, and respiration 18. The chest was symmetrical with equal respiratory excursions. There were fine rales in the base of the left lung. The heart rate was normal, but the rhythm irregular with frequent premature contractions. The abdomen was flat and soft. Pulsation synchronous with the heart beat was visible in the middle of the abdomen. No definite mass was visible; however, there was a mass about the size of a large orange palpable beneath the umbilicus. It could be moved several centimeters bilaterally but not superiorly or inferiorly. This mass was expansile and pulsatile. The prostate was smooth with minimal hypertrophy. Otherwise the examination was essentially negative.

Laboratory. The blood count and urinalysis were within normal limits. There were 1 to 2 blood cells per high power field on microscopic urinalysis. The Wassermann and Mazzini serologic tests were negative.

Roentgenologic findings. Intravenous urogram revealed normal kidneys and ureters without displacement or calculi. The scout film revealed minimal sclerosis of the terminal branches of the aorta. Cholecystogram revealed a phrygian cap without other abnormality. Gastrointestinal series revealed a normal esophagus and stomach. There was a clover-leaf deformity of the duodenum with active ulceration. The third portion of the duodenum was arched upward and there was a 30 per cent 5 hour residue in the stomach. The displacement of the duodenum suggested a retroperitoneal origin of the abdominal mass. Barium enema revealed a few small sigmoid diverticula, but was otherwise negative. Roentgenogram of the chest revealed linear fibrosis in the apices of both lungs. Roentgenogram of the dorsolumbar spine showed calcification of the ninth and eleventh dorsal intervertebral discs. Electrocardiograph showed frequent premature ven-

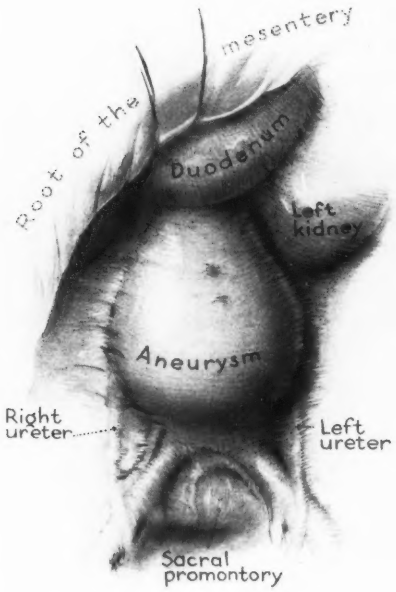

Fig. 1.

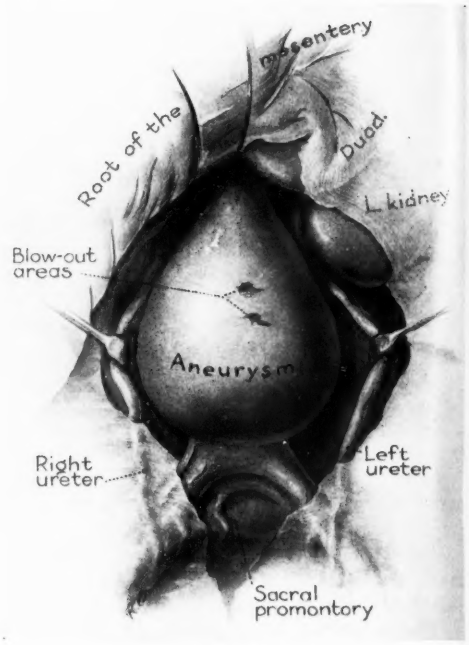

Fig. 2.

Fig. 1. With the abdomen open and the abdominal viscera retracted, the aneurysm is clearly visualized.

Fig. 2. The posterior parietal peritoneum is opened in the midline from below the sacral promontory to the level of the duodenum. The ureters are retracted. The superior and inferior mesenteric arteries are not visualized.

tricular beats and myocardial damage. The abdominal mass was never visible with x-ray studies.

An exploratory laparotomy was performed on February 9, 1951. At the time of surgery a large fusiform aneurysm, measuring apparently 8 by 12 centimeters, was encountered extending from the level of the duodenum to the bifurcation of the aorta (Fig. 1). No vessels were seen emerging from this aneurysm although no dissection was done at this time. There were, however, two small, thinned out areas located on the anterior surface of the aneurysm which were thought to represent "blowout" areas. During the uneventful convalescence from the laparotomy it was decided that because of the poor prognosis in general and the probability of rupture of the blowout areas in particular, some form of definitive treatment was indicated. On March 5, 1951 the patient again underwent surgery—a laparotomy—at which time the thin peritoneum overlying the aneurysm was divided longitudinally and retracted laterally on both sides (Fig. 2). The iliac arteries were partially mobilized and surrounded with 2 to 3 layers of reactive cellophane[1] at their junction with the terminal aorta. A cuff of reactive cellophane was then placed over and tucked beneath the aorta above the aneurysm. The duodenum was partially mobilized for this procedure. Next, the ureters were mobilized and retracted laterally. Three layers of reactive cellophane were then placed over the aneurysm and tucked beneath it on both sides. The vena cava was not visible beneath the aneurysm. Then a layer of nonreacting cellophane was placed on top of the reactive cellophane and carried beneath the ureters laterally and sutured to the retroperitoneal tissues, thereby preventing contact of the reactive cellophane with the ureters or parietal peri-

[1]Reactive 1.5 mil polythene.

Fig. 3.

Fig. 3. Reactive cellophane surrounds the iliac arteries at the bifurcation of the aorta and the aorta proximal to the aneurysm. Several layers of reactive cellophane are placed over the aneurysm and tucked beneath it. Nonreactive cellophane covers all of the reactive cellophane and is carried laterally beneath the ureters to prevent contact of the reactive cellophane with the ureters and peritoneum. This plate does not show the nonreactive cellophane which covers the reactive cellophane that surrounds the iliac arteries and the aorta proximal to the aneurysm.

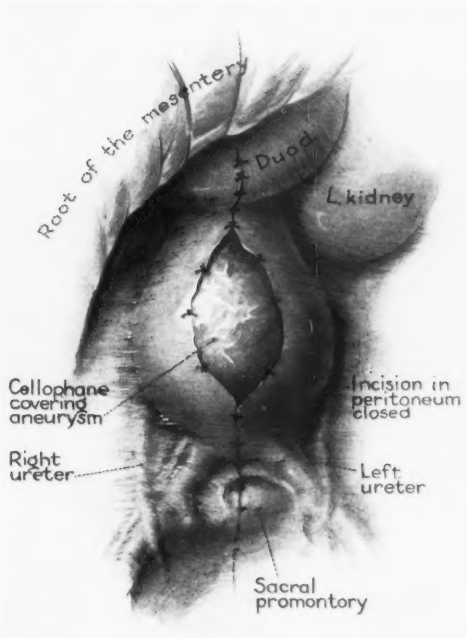

Fig. 4.

Fig. 4. The posterior parietal peritoneum is closed. Over the apex of the aneurysm the peritoneum is too thin to be approximated so it is sutured to the cellophane.

toneum (Fig. 3). The thinned out parietal peritoneum could not be reapproximated in the midline over the aneurysm, so it was sutured to the superficial layers of nonreactive cellophane, thereby leaving the abdominal viscera exposed only to the small area of nonreactive cellophane in the midline (Fig. 4).

Convalescence from this operative procedure was stormy. His temperature ranged from 99 to 101 degrees F. for 20 days following surgery. On the fifth postoperative day he developed partial intestinal obstruction requiring Cantor intubation with continuous suction for 3 days. He had considerable abdominal pain for about 10 days following surgery. Two weeks following surgery he developed swelling of the entire right leg. There was a negative Homans' sign and no calf muscle tenderness. This swelling persisted for 2 weeks before it completely subsided and then he developed a similar swelling of the left leg, which persisted for 3 weeks. This swelling was attributed to edema involving the iliac veins as a result of the presence of the reactive cellophane. We cannot explain the difference in the time of onset in the different legs. About 30 days following the second operation he was ambulatory with minimal swelling of the left leg. He was ready for discharge from the hospital when laryngitis and upper respiratory infection required further care. Finally, on the 54th postoperative day he was discharged, at which time he returned to his home in Columbus, Ohio.

In November, 1951, nine months following surgery, he had a follow-up examination. At

that time he had gained 15 pounds in weight. There was no swelling of either leg. There was no discernible change in the size of the aneurysm; however, it was less mobile laterally, and was considerably firmer to palpation. He had occasional minor episodes of abdominal discomfort and continued to complain of pain in the joints of his hands and left shoulder. He stated that he became tired after walking 8 to 10 blocks. On March 22, the patient returned to the hospital at my request for a 1 year follow-up examination. The mass had not increased in size and felt considerably firmer than prior to surgery. He complained of intermittent episodes of lower abdominal discomfort. His appetite was good and his bowel movements were normal. There was no swelling of either leg. Pulsations in the feet were palpable. His condition is satisfactory at this time.

CONCLUSIONS

1. One case of abdominal aortic aneurysm treated with reactive cellophane is presented.

2. It is believed that surgical treatment in this case prevented imminent rupture of the abdominal aortic aneurysm and prolonged the patient's life.

3. A plea is made for more reports on the surgical treatment of this condition.

ADDENDUM.—This patient died on June 28, 1952 (15½ months after surgery) of a massive upper gastrointestinal hemorrhage. Autopsy revealed a rupture of the aneurysm into the duodenum.

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THE USE OF MAXIMAL SIZE VENA CAVA AUTOGRAFTS TO BRIDGE EXPERIMENTAL AORTIC DEFECTS IN DOGS

I. Studies of Collateral Circulation and Venous Pressure Following Resection of Long Segments of Inferior Vena Cava

ROBERT A. NABATOFF, M.D., ARTHUR S. W. TOUROFF, M.D., MILTON GROSS, B.A., and SIGMUND BRAHMS, M.D., New York, New York

GREAT strides have been made in the field of cardiovascular surgery during the past decade, and the need for an effective method of bridging blood vessel defects has become especially apparent during the past few years. End-to-end anastomosis following excision of a segment of artery is an ideal procedure, but loss of arterial substance often makes such a procedure impossible. Prostheses have been used with varying degrees of success, but, unfortunately, they have not proved uniformly successful.

Gluck and Exner were among the first to report studies concerning vein grafts. However, their experiments for the most part were unsuccessful because of infection, thrombosis, or hemorrhage. Subsequently, Carrel (1, 2, 3) and Guthrie (3) demonstrated that blood vessels could be grafted successfully. In 1949, Johnson, Kirby, Greifenstein and Castillo utilized fresh segments of inferior vena cava to replace defects of the abdominal aorta. In 1951, Macpherson, Nabatoff, Deterling, and Blakemore successfully used preserved venous homografts to bridge aortic defects.

In the transplantation of any tissue, it has long been known that autografts are superior to homografts. A comparative study of fresh arterial autografts and homografts was carried out by Yamanouchi who found no alterations in transplanted autografts. The homografts were observed by him for as long as 74 days. At the end of 10 days, periadventitial fibroblastic proliferation and a well defined media were noted. At 4 weeks, the media was semi-necrotic; slight degenerative changes were noted in the elastic fibers. These alterations progressed steadily; and, by the seventy-fourth day, the media was completely necrotic and moderately thinned. In addition, the elastic fibers were fragmented. Lexer demonstrated that necrosis was almost never found in autografts and that the histologic findings were normal even after 1 year.

It appears that some constitutional factor prevents normal growth and development of homografts. The graft seems to act merely as a scaffold that supports the fibrous tissue which is formed by the host. Since autografts appeared to be superior to homografts, we carried out long term experiments to determine the value of autogenous vein grafts as replacements for defects of the abdominal aorta. It seems to be agreed that, in general, vein grafts are satisfactory for the purpose of bridging defects in small or medium-sized arteries. However, in the past, surgeons have been reluctant to employ vein grafts in such large arteries as the aorta because of the strong possibility that the graft would not withstand the high arterial pressure. Short segments of inferior vena cava have been utilized successfully in various experiments, but we have been unable to find any reference to detailed long term studies concerning the fate of long segments of autogenous inferior vena cava grafts.

If vein grafts proved to be entirely adequate over long periods of time, certain problems posed by blood vessel grafting obviously would be greatly simplified. (It is almost always relatively easy to excise suitable autogenous

From the Laboratories and the Surgical Service of Dr. Arthur S. W. Touroff, The Mount Sinai Hospital, New York.

vein grafts, and there is little danger of compromising the return circulation. Furthermore, the immunological problems posed by the use of homografts would be obviated.)

Accordingly, we excised segments of inferior vena cava of large mongrel dogs, from a point immediately below the renal vessels down to the bifurcation of the iliac veins (8 to 13 cm. in length), and used them immediately to replace excised portions of the adjacent abdominal aorta. The present report concerns the development of collateral circulation and other sequelae secondary to vena cava resection. In future reports, long term studies of the gross anatomy, histology, and elasticity of autogenous long vein grafts will be presented.

EXPERIMENTAL METHODS

Using large mongrel dogs, the inferior vena cava was exposed through a long midline abdominal incision under intravenous nembutal anesthesia. Packing the abdominal viscera to the right, the posterior peritoneum was incised and the inferior vena cava mobilized from its bed by ligating all of the branches between the renal and iliac veins. It usually was necessary to ligate and divide 3 lumbar branches and the right spermatic vein. (Care was taken to ligate all of the branches flush with the vena cava so that there would be no aneurysmal formation or "blowouts" when the graft was sutured into the aortic defect.) The abdominal aorta was then mobilized in similar fashion, ligating all branches of the segment to be excised. This usually included the lumbar arteries and the inferior mesenteric artery. The segment of aorta that was excised was somewhat shorter than the length of the vein graft because the ends of the aorta retracted considerably when the aorta was divided and a portion was removed. The aortic adventitia was removed from the sites of subsequent anastomosis. The segment of vena cava then was excised and flushed through with a mixture of heparin and saline solution. Rubber-shod serrefine clamps were applied to the aorta, and a segment of suitable length was excised. The vein graft next was employed to replace the aortic defect, using No. 5 zero Deknatel silk on a No. 9 curved needle for the anastomosis. (The proximal suture was performed first, because of the tendency of the aorta to slip from the serrefine clamp at that level.) A continuous everting mattress suture was used for the posterior approximation; interrupted mattress sutures were employed anteriorly. Following completion of both anastomoses, the serrefine clamps were removed; the distal clamp was removed first (Fig. 1). The posterior peritoneum then was closed loosely over the graft.

Twenty dogs have been operated upon up to the present time. The length of inferior vena cava that has been resected has varied greatly in different animals, and not necessarily in direct proportion to the size of the animal. This has been due to variations in the level of the renal and iliac vessels. The largest possible animals were used (20 to 30 kilograms); and if it was found at exploration that the desired segment of cava was less than 8 centimeters in length, it was not utilized as a graft. In 15 dogs, the segment of vena cava was 8 centimeters or more in length. In the other 5 animals the cava was shorter than 8 centimeters. In the latter animals, the caval segment was excised so that the dogs could be used for additional studies concerning the sequelae secondary to vena cava resection. All animals were given penicillin in oil intramuscularly on the day of operation and every day thereafter for 4 days. Anticoagulants were not used.

In order to study postoperative sequelae, venous pressures were recorded in the popliteal vein immediately before operation, immediately following operation, and at frequent intervals for as long as 5 months after operation. All recordings were made with the dog in the supine position, with the limb at the level of the heart. The usual venous pressure apparatus was used, employing a No. 18 gauge needle. The only recording that was made with the animal under anesthesia was the one immediately following operation.

In order to supplement the venous pressure studies, venograms were performed at frequent intervals after operation. With the dog under intravenous nembutal anesthesia, the femoral vein was mobilized and 20 cubic centimeters of 35 per cent diodrast were injected rapidly. Serial roentgenograms then were

taken, in order to visualize as many collateral branches as possible.

The development of collateral circulation in the superficial tissues was studied further by means of infrared photographs. These were taken after the body wall had been shaved completely. These photographs were compared with ones of normal control animals.

Just before the animals were sacrificed, the veins were injected with plastic material so that the entire venous system could be examined thoroughly at autopsy. To accomplish this, the superior and inferior venae cavae were exteriorized and cannulated close to their entrance into the heart. The animals were exsanguinated, and normal saline then was injected into the femoral vein until the fluid coming from the cavae was clear. The veins next were filled with vinylite, as described by Lindbow, Hale, and Lindskog, by injecting the material into the femoral vein. At autopsy, the entire venous pattern was clearly delineated and even the smallest branches could be visualized.

Fig. 1. Photograph of 13 centimeter inferior vena cava graft used to bridge defect of abdominal aorta. Arrows indicate sites of anastomoses. Area to right of graft represents bed of the excised inferior vena cava.

EXPERIMENTAL RESULTS

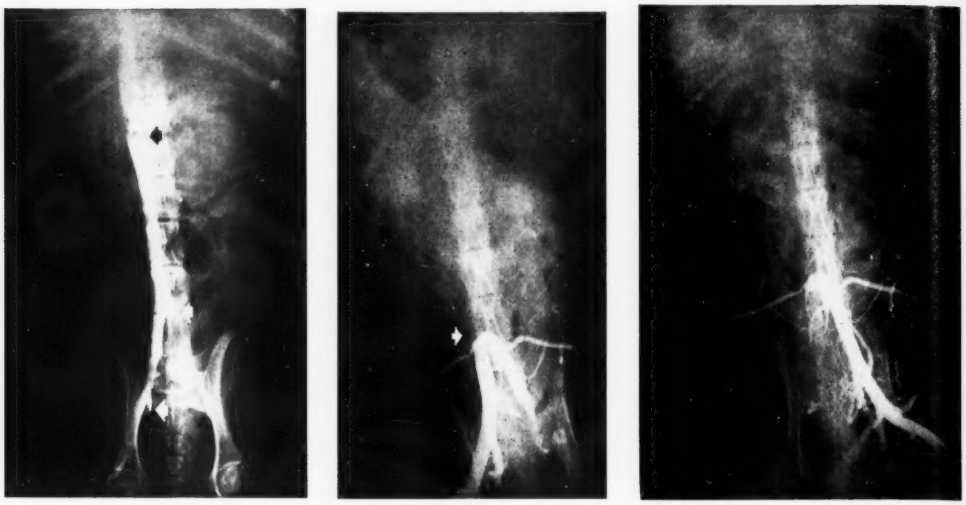
The present report is based upon detailed studies of 14 animals that survived operation. There were 6 deaths in the entire operative group of 20 dogs. Four deaths occurred in the immediate postoperative period from respiratory complications. The fifth dog died 1 week after operation and, at autopsy, the entire graft was found to be thrombosed. The sixth death occurred 1 month after operation, as a result of pneumonia; the operative site was found to be intact. Of the 14 animals that survived, none developed edema of the extremities nor any evidence of venous congestion. All appeared normal in every respect. In several dogs, the veins of the abdominal wall were noted to be prominent for several weeks.

Venous pressures. The venous pressures of all animals were found to be quite similar. The normal preoperative pressures ranged from 6 to 10 centimeters of saline. Immediately following excision of the segment of inferior vena cava, the pressure invariably rose to 3 to 4 times the aforementioned level. Within 4 to 6 hours, it was approximately twice the preoperative level, and within 24 to 48 hours, it had fallen almost to normal. In no instance did the venous pressure remain significantly elevated after the third postoperative day. Repeated observations during periods as long as 12 months revealed that the pressures remained at these normal levels.

Venograms. Serial venograms demonstrated the rapid development of collateral vessels. Figure 2a represents a normal venogram. Four hours postoperatively (Fig. 2b), the iliac veins appeared somewhat dilated and collateral vessels were sparse. Twenty-four hours after operation (Fig. 2c), the collateral network was significantly richer. At the end of 1 week (Fig. 2d), the collaterals had become extensive.

Infrared photographs. No significant dilatation of the superficial abdominal veins was noted, the circulation through the intra-abdominal vessels apparently being adequate to compensate for resection of long segments of inferior vena cava.

Injections of vinylite. Injection of vinylite into the venous system, immediately prior to sacrificing the animals, confirmed the fact that the return circulation was blocked at the site



a b c

d

Fig. 2. a, Venogram in normal dog. Thirty-five per cent diodrast injected into the right femoral vein. Upper arrow indicates level of renal veins. Middle arrow indicates left common iliac vein. Lower arrow indicates right internal iliac vein. b, Venogram performed 4 hours postoperatively. Arrow indicates lower site of ligation of inferior vena cava. Note that left common iliac and right common iliac veins are markedly dilated. Collateral vessels are beginning to form via the lumbosacral, vertebral, and internal iliac veins. c, Venogram performed 24 hours after operation in the same animal. Diodrast injected into left femoral vein. An increase in number and size of collateral vessels is apparent. d, Venogram performed 1 week postoperatively. Note rich collateral network at this time.

of the lower ligation of the vena cava and was rejoining the cava just above the renal veins. Autopsy revealed that the veins which formed the major collateral network developed via the vertebral, internal iliac and dorsal abdominal wall veins. The abdominal wall vessels seemed to anastomose and then empty into the inferior vena cava via the inferior phrenic (phrenicoabdominal) vein, immediately above the renal vessels. Large veins developed along the course of the ureter, and these drained into the renal vessels. Thus, the majority of the collateral veins emptied into the inferior vena cava immediately above the proximal ligation site (Fig. 3 and 4). (The collateral potential is so extensive in the dog that anastomoses between the superior and inferior caval systems apparently are not called into play.)

Fig. 3.

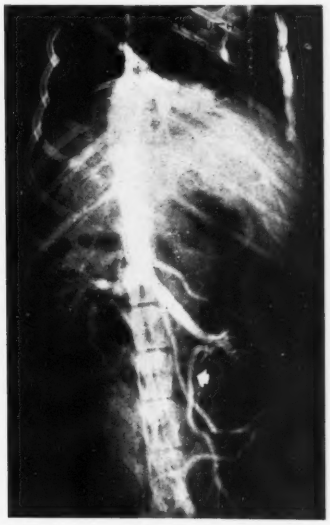


Fig. 4.

Fig. 3. Injection of vinylite 6 weeks following excision of inferior vena cava (between the renal and iliac veins). Note development of large collaterals via the internal iliac (arrow) and lumbosacral veins. Inferior vena cava above upper ligation site is visualized poorly.

Fig. 4. Injection with vinylite 5 months after operation. Note marked enlargement of ureteral veins (arrow), which anastomose with internal iliac vein below (not clearly seen) and renal vein above. Filling of inferior vena cava (via the collateral vessels) immediately above the upper ligation site now is demonstrated clearly in the photograph. The inferior phrenic vein, receiving blood from the vessels of the abdominal wall also is visualized readily.

Injection studies of the veins of dogs have been carried out by Miller. According to his report, 2 satellite veins which course along the ureter are consistently found at the hilum of the kidney. These veins anastomose with the renal vein. They communicate caudally, via the pudendal venous plexus, with the hypogastric vein. The inferior phrenic vein receives blood from the dorsal portion of the abdominal wall, and a caudal branch anastomoses with the ascending branch of the deep circumflex iliac vein. In our experience, these two systems and the vertebral veins formed the major portion of the collateral network following resection of long segments of the inferior vena cava.

Some of the animals operated upon have been observed now for more than 2 years and have not demonstrated untoward sequelae. Detailed histological and elasticity studies of the vein grafts are being carried out, and the results will be presented in another report. It is hoped that these long term studies will help to clarify the relative value of venous autografts as opposed to arterial homografts when used to bridge defects of large arteries.

SUMMARY AND CONCLUSIONS

1. Segments of inferior vena cava between the renal and iliac veins apparently may be excised with impunity and used to bridge experimental aortic defects in dogs. Our animals have been observed for more than 2 years and, thus far, have not exhibited untoward sequelae.

2. Venous pressures in the popliteal vein return rapidly to essentially normal levels after transient elevation.

3. Postoperative venograms demonstrate a rich collateral return circulation, largely via the vertebral, internal iliac, and dorsal abdominal wall veins. This network becomes

well developed within a week. Infrared photographs and injection studies with vinylite have confirmed the aforementioned findings.

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AN EXPERIMENTAL STUDY ON THE REDUCTION OF URETERAL REFLUX

I. T. RIEGER, M.D., Bloomington, Indiana, and JACKSON HARRIS, M.D., Albuquerque, New Mexico

ONE of the greatest problems associated with ureterointestinal anastomosis is that of acute and chronic pyelonephritis, caused by reflux of intestinal contents up the ureters. The "submucosa tunnel principle," in which the ureter runs for a short distance in the wall of the bowel before opening into it, as in the Coffey techniques, has partly solved this problem. The ureters are compressed as pressure in the lumen of the bowel rises so that the tendency to reflux is lessened. However, obstruction at the anastomotic site due to constriction of the tunnel about the ureter causes a high incidence of hydronephrosis. This principle had been widely utilized for many years until Nesbit and Cordonnier demonstrated that with the direct, end to side, mucosa to mucosa technique the incidence of postoperative stricture at the site of anastomosis was much less than with the tunnel procedures.

Soon after the Nesbit technique had been put into use, it became apparent that in this type of anastomosis ureteral reflux would be a problem. Some indications of this were: the findings of colonic gas in ureteropyelograms, the findings observed in perfect retrograde pyelograms during rectal study with contrast media, and the findings reported by Whisenand and Moore of gas and feces discharged from nephrostomies following bilateral ureterointestinal anastomosis.

Working independently with dogs, Woodruff, Cooper, and Leadbetter and Weyrauch and Young studied various types of ureterointestinal anastomoses. Both groups found that with the Nesbit anastomosis more ureteral reflux and less obstruction occurred than with the tunnel techniques. If ureteral reflux could be prevented or reduced in the Nesbit technique, it would be expected that end results would improve.

Berg in 1907, reported 5 cases of extrophy of the bladder in which he transplanted the ureters to an isolated segment of small bowel anastomosed to the sigmoid colon. He stated that the results in 2 cases were satisfactory.

Mann and Bollman demonstrated that an isolated loop of small intestine anastomosed in an antiperistaltic manner between the skin and the gastrointestinal tract in the dog permitted no fecal spillage if the isolated loop was more than 15 centimeters in length. Peterson and Cole believed that the antiperistaltic loop should be at least 30 centimeters long to prevent regurgitation or intestinal contents into the biliary tree. This is the principle used in the Roux Y procedure for biliary obstruction.

Gilchrist, Merricks, Hamlin, and Rieger, working with dogs and humans, and Bricker and Eiseman, with humans alone, demonstrated that both ureters could be transplanted to a substitute bladder made of the isolated cecum and a segment of terminal ileum 15 to 20 centimeters long.

McLean and Fais found that 20 centimeter segments of terminal ileum could be substituted for one or both ureters in dogs.

We thought that if an isolated loop of bowel were anastomosed in an antiperistaltic manner to the sigmoid colon and the ureters then transplanted to the proximal end of this loop, ureteral reflux would be prevented or reduced because peristalsis of the isolated loop should prohibit colonic contents from reaching its proximal end. We decided to use the terminal ileum as the isolated loop.

Because in this preliminary work we wished to establish the maximum length of ileal loop which would be compatible with life in regard to absorption of urine and to avoid the prob-

From the Rush Departments of Urology, Surgery, and Pathology, Presbyterian Hospital, Chicago, Illinois, in affiliation with the University of Illinois College of Medicine.

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Fig. 1. Necropsy specimen. Arrows point to urinary bladder, isolated segment of ileum, and sigmoid colon, all of which have been opened. Note 3 calculi in sigmoid colon clinging to ends of silk sutures projecting into the lumen.

lems of ureteral transplantation in dogs, the dome of the bladder, rather than the ureters, was anastomosed to the proximal end of the ileal loop. Any changes in blood chemistry would then be due solely to absorption of urine and not to upper urinary tract disturbances due to difficulties with ureteral transplants. The urethra would be ligated and divided so that all urine would pass from the bladder through the ileal loop into the sigmoid colon. The reaction of the bladder mucosa would serve as an indicator of repeated contamination of the proximal end of the isolated loop by colonic contents.

METHODS AND RESULTS

Twenty-four mongrel dogs were operated upon with 9 immediate postoperative deaths due to surgical, anesthetic, and miscellaneous causes.

Varying lengths of the terminal ileum from 15 to 65 centimeters in length were isolated and anastomosed to the sigmoid colon in an antiperistaltic manner. Continuity of the bowel was re-established by end to end ileoileostomy. After the urethra was doubly ligated and divided, the dome of the bladder was anastomosed to the proximal end of the ileal loop.

These dogs were then followed with blood chemistries which included nonprotein nitrogen, carbon dioxide combining power, and blood chlorides. Dogs that survived were killed by overdoses of nembutal at the end of 4 months. Dogs that were near death were killed so that no postmortem contamination of bladder urine might occur. Autopsies, including cultures of bladder urine, were performed on all.

Thirteen dogs with ileal loops 15 to 20 centimeters long were operated upon with an immediate mortality of 4. The remaining 9 dogs survived with slightly altered blood chemistries. In general, the nonprotein nitrogen was slightly elevated, the carbon dioxide combining power was moderately depressed, and the chlorides were only very slightly elevated or within normal limits.

All dogs were sacrificed at 4 months. At autopsy, all showed varying degrees of cystitis with the bladder urine grossly contaminated with various organisms which included Bacillus proteus, Escherichia coli, Streptococcus hemolyticus, Streptococcus viridans, and diphtheroid bacilli. All anastomoses were patent. Hair was found in the bladder of 1 dog. The upper urinary tracts were normal, except for 1 dog that had a unilateral pyonephrosis and another dog that had a dilated ureter.

Seven dogs with ileal loops 35 to 40 centimeters long were operated upon with an immediate mortality of 4. The surviving 3 dogs were killed after 4 to 6 weeks as they were in terminal uremia. The nonprotein nitrogen rose steadily to uremic levels. The chlorides rose slightly for a period of 2 weeks and then fell to subnormal levels as dehydration, malnutrition, and uremia occurred. The carbon dioxide combining power declined to around 30 volumes per cent where it remained. Even when uremia became profound severe acidosis did not develop, possibly because of the lowered blood chlorides. All bladder urine was infected, although there was not the severity of cystitis encountered in the previous group.

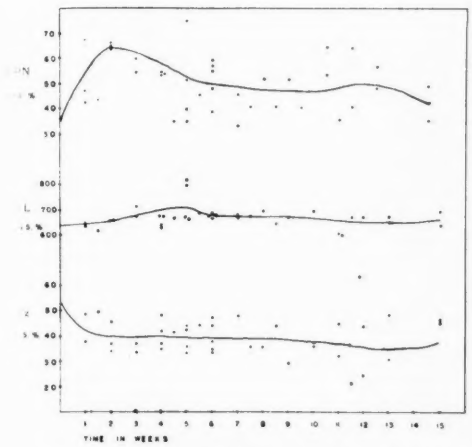

Fig. 2. Graph showing postoperative blood chemistry changes in dogs with ileal loops 15 to 20 centimeters in length.

One dog was found to have feces in the bladder. The upper urinary tracts were normal.

Four dogs with ileal loops 45 to 65 centimeters long were operated upon with an immediate mortality of 1. The remaining 3 dogs were so sick at the end of 1 week that they were sacrificed. All 3 were uremic with very high nonprotein nitrogen levels. The carbon dioxide combining power in 2 of them was very low, being only slightly depressed in the remaining dog. The chlorides were depressed slightly. All bladder urine was infected. Gross cystitis was not apparent, presumably because of the brief duration of the experiment. The upper urinary tracts were normal.

DISCUSSION

As previously stated, one of the greatest problems associated with diversion of urine by ureterointestinal anastomosis is ureteral reflux of colonic contents, resulting in acute and chronic pyelonephritis.

By interposing an antiperistaltic segment of terminal ileum between ureters and sigmoid colon, we hoped to reduce or prevent ureteral reflux. Peristalsis should reduce contamination of the ureters at the proximal end of the ileal loop. In this experiment the dome of the urinary bladder, rather than the ureters, was anastomosed to the proximal end of the ileal loop. This was done as it was necessary to establish the length of ileal loop that would be compatible with life in regard to urinary absorption. We desired to avoid blood chemistry changes from the well known difficulties with ureteral transplants in dogs. Any blood

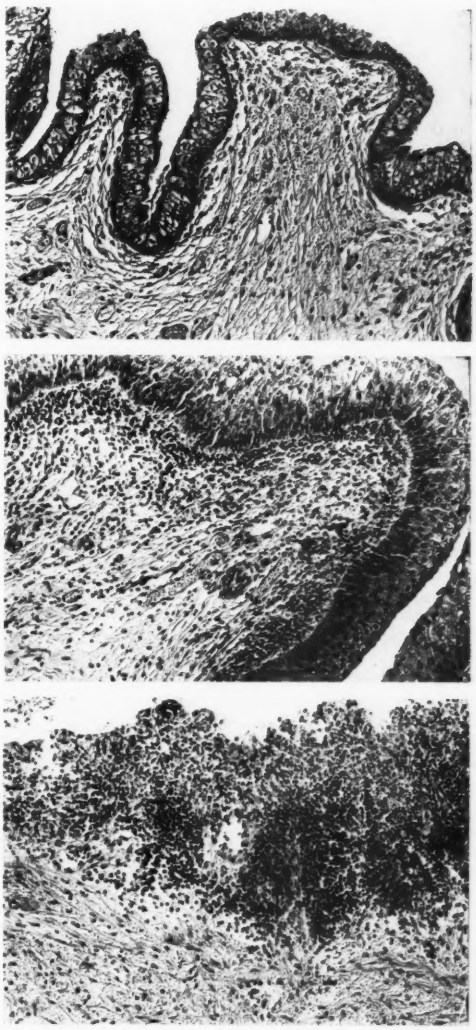

Fig. 3. Photomicrographs of sections of the urinary bladder taken from 3 dogs with ileal loops 15 to 20 centimeters in length, illustrating the varying histological picture. Gross cystitis was apparent in all, though variable in severity, and areas of normal appearing mucosa were found.

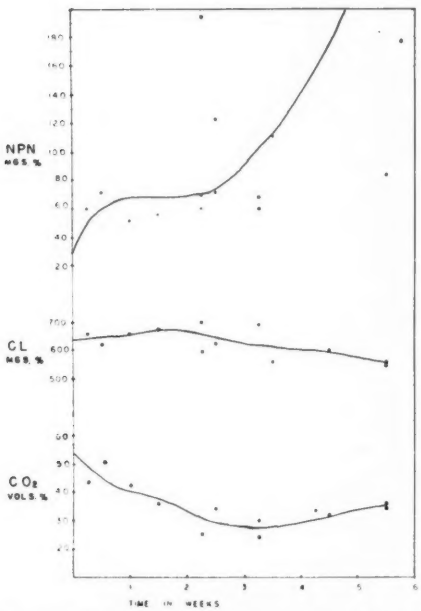

Fig. 4. Graph showing postoperative blood chemistry changes in dogs with ileal loops 35 to 40 centimeters in length. This length of ileum was not compatible with life, all dogs becoming uremic in 4 to 6 weeks from excessive absorption of urine.

chemistry changes were due solely to absorption of urine from ileal loop and colon. With the urethra ligated, all urine passed directly from the bladder into the ileal loop and thence to the sigmoid colon. A residual urine in the bladder did not exist. Clinically, of course, ureters would be substituted for the bladder.

We have established that ileal loops of 15 to 20 centimeter lengths permit survival of the dog with slightly altered blood chemistries, similar to those following ureterosigmoid anastomosis. Ileal loops 35 centimeters and over in length resulted in death from urinary absorption. Infection of the bladder was not prevented by this antiperistaltic loop. Therefore, ureteral reflux, following transplantation of the ureters to a similar ileal loop, as would be done clinically, could not be entirely prevented or rendered harmless. It is likely, however, that the degree of ureteral reflux could be materially reduced by this method. Further experimentation is needed.

In the dogs that died, death was due not only to absorption of urine from the ileal loop, but also to absorption from the colon. The blood chlorides did not vary greatly from their slightly elevated levels, except when the animals were dehydrated and in uremia. In this state the chlorides usually dropped below normal values. The carbon dioxide combining power seemed more closely related to the nonprotein nitrogen than to the chlorides, being depressed when the nitrogen was elevated. The blood chlorides were often within normal limits when the carbon dioxide combining power was depressed.

Mention may be made of the almost total absence of pathologic changes in the upper urinary tract. This might have been due to the intact ureterovesical valves, as well as the antiperistaltic loop, discouraging ureteral reflux. Given time, the valve function might have been impaired by infection and rendered incompetent as shown by Baker and Miller.

Many questions remain unanswered. It is fairly certain that solving the problem of ureteral reflux in this fashion will add to the other great problem of ureterointestinal anastomosis, namely, acidosis from absorption of urine. In the future we intend to compare a group of dogs with direct vesicosigmoidostomies with a group having ileal loops of a length compatible with life anastomosed between bladder and sigmoid. Attempts will be made to determine the difference in degree of bladder infection, blood chemistry changes, and pressure required to cause regurgitation of contrast media from the colon to the urinary bladder.

SUMMARY

A group of dogs was operated upon in an attempt to find a method of reducing the hazards and occurrence of ureteral reflux following ureterointestinal anastomosis. This was done by interposing an antiperistaltic segment of small bowel between the urinary tract and sigmoid colon in order that peristalsis would protect the urinary tract from contamination by colonic contents. Clinically, the ureters would be transplanted to the proximal end of this isolated loop and the sigmoid colon anastomosed to the distal end. Experimentally, the dome of the urinary bladder was

anastomosed to the proximal end of the isolated loop, and the urethra was ligated so that ...d results would not be confused by difficul...s with ureteral transplants. Continuity of ...e bowel was re-established by ileoileostomy. ...eal loops of 15 to 20 centimeters were com...tible with life in regard to absorption of ...ine at least up to 4 months. Ileal loops 35 ...ntimeters or more in length absorbed so ...uch urine that they were incompatible with ...e. Even these long loops were not of suf...ient length to prevent reflux contamination ... the urinary bladder by colonic contents. A ...rollary may be drawn that infectious ma...rial cannot be entirely prohibited from ure...rs transplanted to similar ileal loops, ...ough probably the degree of ureteral reflux ...th resulting infection can be reduced. More ...perimental work on this problem is necessary

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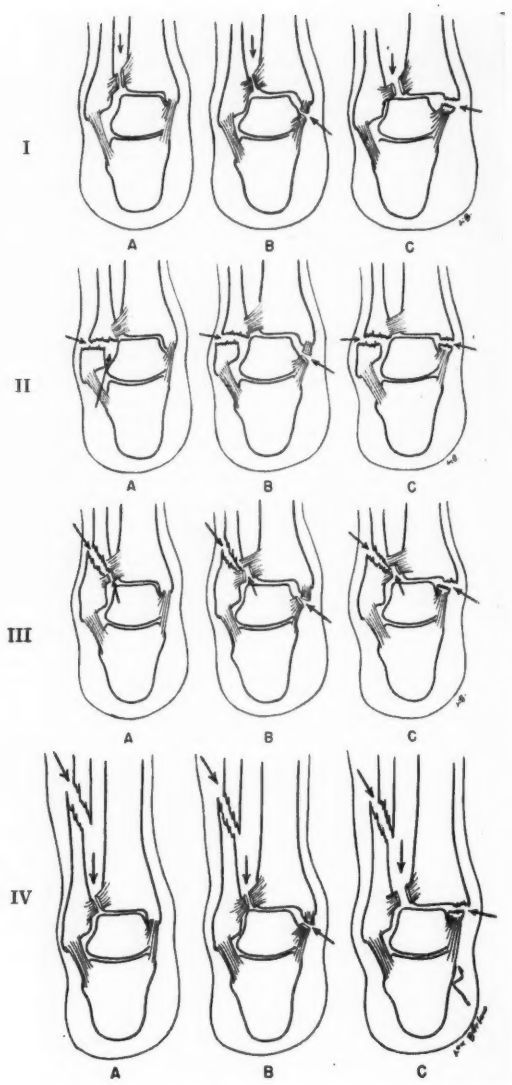


Fig. 1.

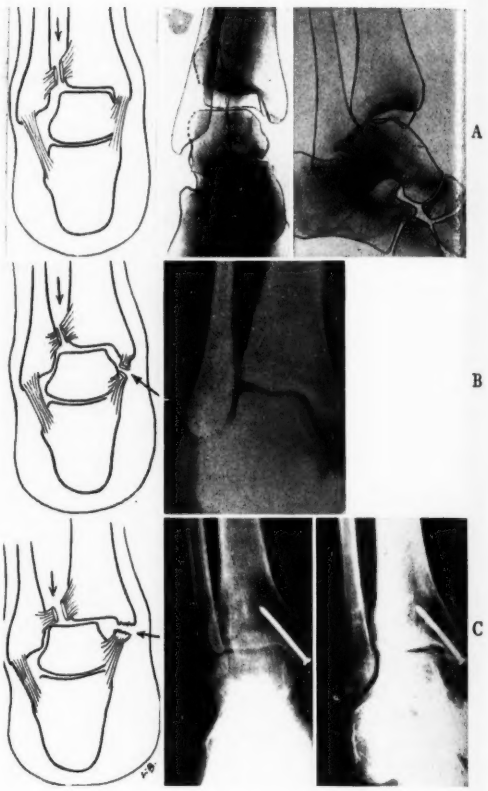


Fig. 2.

Fig. 1. Groups I, II, III, and IV.
Fig. 2. Group I, subgroups A (roentgenograms from *Brit. J. Surg.*, 1942: 29, 359), B, and C.

ANKLE MORTISE INJURIES

VICTOR MAYER, M.D., F.A.C.S., New York, New York, and STANLEY POHLIDAL, M.D., Easton, Pennsylvania

THE general experience with present classifications of ankle mortise injuries has been characterized by their inability to contribute to the proper understanding of the problem involved. In Bonnin's recent text, a most complete historical evolution of classifications is ably presented. The mechanism of injury is used as the basis for previous classifications. To place great reliance on the patient's memory for the mode of injury often leads one to a very inconclusive diagnosis. No fault can be found with the analysis of the injury from these cases in which an accurate and detailed mechanism can be obtained. However, in practice, the procedure is reversed and the mechanism is inferred from the pathological findings. This was noted in an analysis of 60 ankle mortise injuries which we recently completed. We then realized that it was the x-ray study for the most part, plus the clinical examination, which gave the maximum data necessary to plan a course of treatment.

The basic feature to which the ankle joint is reduced must necessarily be the mortise. This is outlined by the distal fibula, tibia, and its all-important syndesmosis. It is the integrity of this mortise which must be preserved with utmost care to insure the perfect end result. Failure to correct any incongruity between the mortise and the talus will forecast disastrous changes in the ankle joint. We have evolved this classification from the functional viewpoint, emphasizing the integrity of the mortise. With the mortise as a frame, the fibula is the hinge upon which this classification swings. A disparity between the mortise and its snug-fitting companion, the talus, may result from fracture of the lateral malleolus, medial malleolus, separation at the distal tibiofibular syndesmosis, and rupture of the medial ligaments. In some instances 1 of these injuries taken singly may rob the mortise of its function. In other cases a combination of 2 or 3 of these findings produces the same effect.

The fibula, as visualized by x-ray examination, was found to be an excellent variable. Four main groups were represented. The first had an intact fibula. In the second, a fracture of the fibula was noted below the tibial plafond, which is transverse in direction. The third group was characterized by a fracture of the fibula in the zone of the distal tibiofibular syndesmosis. The fracture line was most often seen to be either a short or long oblique, extending anteriorally from proximal to distal. On occasions this fracture line had its proximal half oblique and distal half transverse. In the fourth and last group, the fibular fracture was located proximal to the level of the syndesmosis. It could vary from a long oblique to a transverse fracture and could be situated as high as the neck of the fibula. It is of interest to note that after arriving at this classification the authors came upon a report by Obletz in which he suggested the use of the fibula as a basis for a classification.

An analysis of the injuries associated with the above groups showed that combinations could be readily devised by using the following 3 categories: (a) intact medial ligaments and medial malleolus, (b) tear of medial ligaments, and (c) fracture of medial malleolus.

Anterior and posterior lip fractures may be superimposed on this classification but do not alter the basic mortise injury. When these fractures are present, they can be considered as a disturbance of a mortise visualized in an anterior-posterior plane.

In Figure 1 we have diagrammatically illustrated the 4 groups of ankle mortise injuries together with the combinations of the subgroups.

Specific examples will be presented in the following pages demonstrating each of the subgroups mentioned.

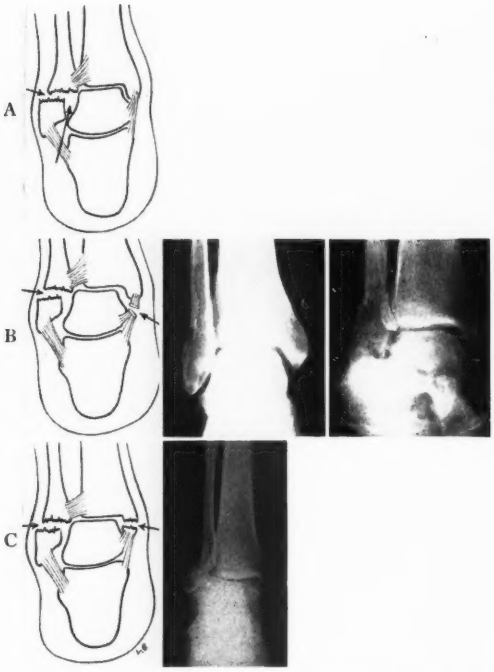


Fig. 3. Group II, subgroups A, B, and C, with specific examples.

GROUP I

In group I subgroup A (Fig. 2, A) a tibiofibular diastasis is found without any accompanying fracture of the fibula. This is a great rarity and it was necessary to illustrate this condition from the literature (3). In this instance a single factor was sufficient to disrupt the mortise.

Subgroup B (Fig. 2, B) demonstrates an intact fibula in the presence of torn medial ligaments. In the illustration the latter is represented by a secondary calcification in the region of the medial malleolus. The separation at the distal tibiofibular joint is clearly seen.

In subgroup C (Fig. 2, C), a postoperative roentgenogram is seen in which the site of the screw used to reduce the widened distal tibiofibular joint is still visualized. The screw maintaining the fracture of the medial malleolus can be seen.

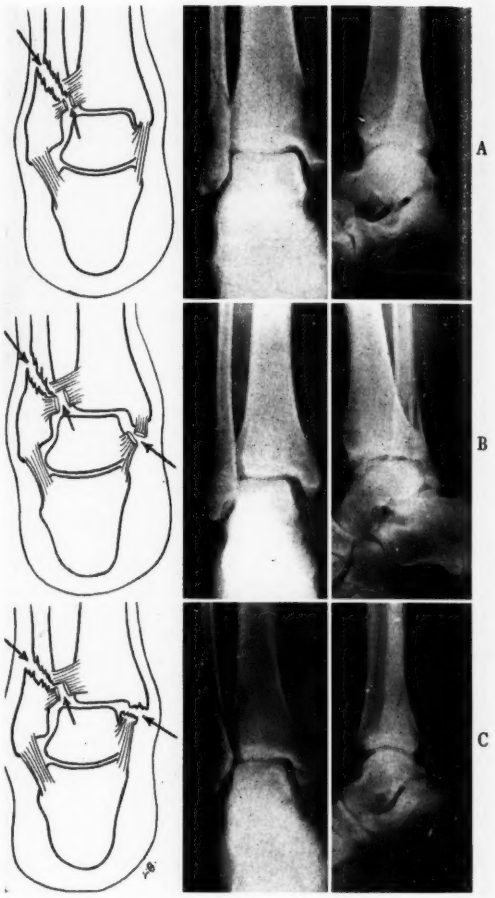


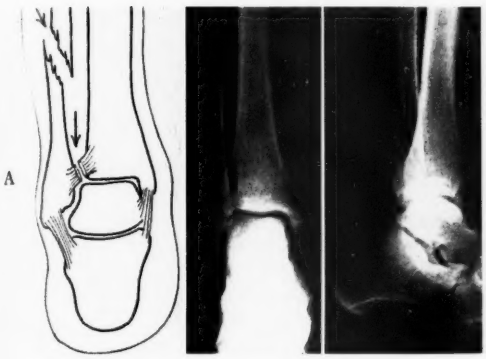
Fig. 4. Group III, subgroups A, B, and C.

GROUP II

The second group is characterized by a fracture of the fibula below the tibial plafond. While subgroup A exists as a possibility, we have not been able to find a case in our series, wherein such a fracture was present without concomitant injury to the medial malleolus or medial ligaments. This is presented diagrammatically in Figure 3, A.

In subgroup B the fibular fracture is associated with a tear of the medial ligaments (Fig. 3, B).

The fracture of the medial malleolus plus the lateral malleolus at the level of the tibial



afond are clearly depicted in Figure 3, C, ustrating subgroup C.

GROUP III

The keynote of group III is the fracture of e fibula obliquely through the level of the biofibular syndesmosis. Subgroup A, which illustrated in Figure 4, A, demonstrates is type with an intact medial malleolus and edial ligaments but a tear of the distal tibiobular ligaments.

The tear of medial ligaments with the blique fibular fracture is easily seen in Figure , B, resulting in a widened mortise. This a representation of subgroup B.

The coexisting fractures of the medial and lateral malleolus in Figure 4, C, show how this combination can disrupt the mortise. These are the findings in subgroup C.

GROUP IV

The characteristic finding in group IV is the high fibular fracture. In Figure 5, A, illustrating subgroup A, no damage is seen at the medial malleolus or medial ligaments, but separation of the distal tibiofibular joint is present.

Subgroup B with its tear of the medial ligaments is seen associated with a high fibular fracture and rupture of the ligaments of the distal tibiofibular joint (Fig. 5, B).

In the final illustration (Fig. 5, C), the fracture of the medial malleolus common to subgroup C, is seen in combination with the high fibular fracture and tear at the distal tibiofibular syndesmosis.

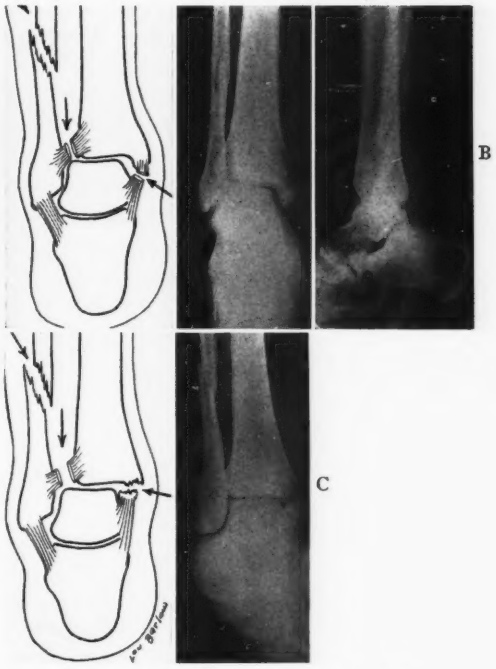


Fig. 5. Group IV, subgroups A, B, and C.

In presenting this clarified picture emphasizing the mortise, the danger of oversimplification exists. However, we believe that it does not act as a distinct barrier to the better understanding of the problem of the mortise injury.

It has been with the increased use of adequate x-ray studies of all ankle injuries emphasizing bimalleolar view and tension films, that the true scope of the damage has been revealed. The full importance of these additional studies cannot be too strongly emphasized.

While every classification has its merits, it is felt that this one has greater value because of its functional approach.

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CONGENITAL ANOMALIES OF THE FIRST BRANCHIAL CLEFT

ROBIN M. RANKOW, M.D., and JOHN M. HANFORD, M.D., F.A.C.S., New York, New York

DEFECTS of the first branchial cleft are rare in the medical literature of the past century. Rathke, His, and Wenglowski have contributed most to the understanding of the morphologic basis for vestigial defects of the entire branchial apparatus.

The majority of congenital sinuses and fistulas of the neck have been derived from defects of the second branchial cleft and the corresponding pharyngeal pouch. These usually begin internally in the region of the tonsillar fossa and terminate in the anterior neck at about the level of the hyoid bone.

In 1923, Frazer discussed vestigial structures of the neck and mentioned that although the persistence of cells representing the first branchial cleft had not been reported yet, they were a distinct possibility. He added that such a vestige would most likely lie below the eustachian tube, behind the tensor palati, and in front of the carotid artery and stylopharyngeus muscle. Also, these defects of the first branchial cleft would open behind and below the angle of the mandible near the anterior border of the upper half of the sternocleidomastoid muscle above the level of the hyoid.

Embryologically, an alternating series of 5 branchial arches and 4 grooves or clefts appear upon the sides of the head of the embryo at the beginning of the fifth week and disappear between the seventh and eighth week of gestation. Corresponding to these ectodermal clefts appear 4 lateral entodermal outgrowths or pharyngeal pouches. A branchial membrane representing the ectoentodermal site of contact normally separates the branchial clefts from the pharyngeal pouches in the human embryo (Fig. 1) (9).

In the course of the development of the tympanic membrane there is a split between this ectoentodermal membrane into which a layer of mesoderm and the chorda tympani nerve invaginate. The ectodermal portion of the first branchial cleft becomes a modified skin with the vascular mesoderm as a base and contributes to the formation of the adult external auditory meatus. The corresponding entodermal portion of the first pharyngeal pouch becomes the tympanic cavity of the middle ear and the eustachian tube.

It is presently believed that congenital preauricular and auricular cysts and sinuses are the result of the defective coalescence of 6 small hillocks of mesenchymal tissue derived from the first and second branchial arches surrounding the first branchial cleft. There has been occasional speculation concerning their origin from the first branchial cleft. However, Streeter minimizes the importance of these hillocks and suggests that the auricle is formed from an intact and continuous primordium. The surface areas of the first and second arches enter into the formation of the auricular primordium which subsequently migrates dorsolaterally without contribution from the first branchial cleft.

In view of this coincidental but uncertain genesis, it has been elected to omit preauricular and auricular defects from this consideration of congenital anomalies of the first branchial cleft.

Hyndman and Light, in 1929, reviewed 90 cases of defects of the branchial system, of which 17 were their own. In this entire group only 1 was suggestive of a first branchial cleft anomaly. Ladd and Gross, in 1938, at The Children's Hospital in Boston, found only 1 first branchial cleft irregularity in a review of 82 branchiogenic anomalies. Neel and Pemberton, in 1945, reported no vestige of first cleft origin in 319 cases of lateral cervical cysts and fistulas seen at the Mayo Clinic. In a review of malformations of the auricle and the external auditory meatus, Altmann confirmed

From the Department of Surgery, College of Physicians and Surgeons, Columbia University, and the Surgical Service of the Presbyterian Hospital, New York.

the extreme rarity of first branchial cleft fistulas from the neck to the external auditory meatus.

Byars and Anderson have emphasized the diagnosis of a first branchial cleft anomaly in the presence of any persistent sinus or fistula high in the neck associated with any external auditory canal discharge without middle ear infection. These authors described 3 examples of these anomalies but did not mention their statistical incidence.

Recently, 2 cases meeting the criteria of first branchial cleft defects were seen at the Presbyterian Hospital. A search of the medical records at this hospital in the past 20 years from 1932 to 1951 revealed 167 reports of all forms of branchial cysts and fistulas (excluding preauricular and auricular defects). Of these, 8 cases were bilateral. In this total of 175 anomalies, 15 patients did not come to operation for various reasons. The remaining branchiogenic anomalies were confirmed both at operation and by histopathological examination. Of this entire series of 160 established defects, only 1 other first branchial cleft vestige was encountered, making a total of 3 such cases. This represented an incidence of 1.8 per cent in the past 20 years.

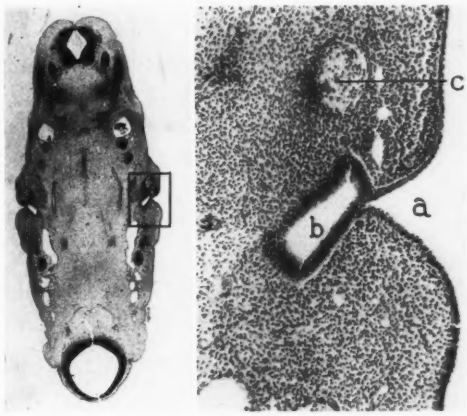
REPORT OF CASES

CASE 1. P.H. No. 777348. S.M., a white female, aged 2 years, was first seen at the Vanderbilt Clinic of the Presbyterian Hospital, in 1930, for a draining sinus in the upper portion of the left anterior neck of 6 months' duration. The swelling persisted during the next 15 years with periodic spontaneous discharges.

In March 1945, lipiodol visualization of the tract was evident to approximately 1 centimeter below the external auditory meatus. A large blob of lipiodol noted in the external ear was presumed to have run in from the outside (Fig. 2).

Clinically, the lesion was believed to be a possible branchiogenic fistula of the first branchial cleft. Physical findings were significant only in the head and neck. The left ear drum was scarred and an orange wax was present in the canal. At the upper end of the sternocleidomastoid muscle, overlying its anterior border, a pinkish, flat, nontender, oval scar with a small central sinus was evident (Fig. 3).

At operation in May 1945, methylene blue was injected into the skin opening of the fistula. The dye was not observed in the external auditory canal. The course of the fistulous tract was described from the skin inward and upward superficial to the posterior belly of the digastric muscle and extending backward to the junction of the cartilaginous and bony parts of the external auditory canal. There was a dense, tough wall at the deep end of the fistulous tract which suggested cartilage. No communication could be made out between the internal end of the tract and the external canal.



a b

Fig. 1. a, A frontal section through the branchial region of a human embryo about 6 weeks of age (length 10.1 mm.) from an original preparation by Dr. William M. Rogers. b, A magnification of the outlined region in *a*, showing the intact branchial or entoectodermal membrane which normally separates the ectoderm of the first branchial cleft *a* from the entoderm of the first pharyngeal pouch *b*. The developing chorda tympani nerve *c* is also shown in this section.

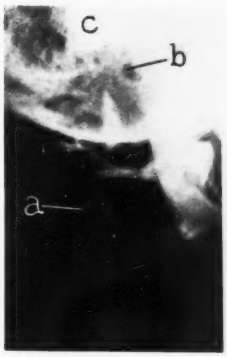
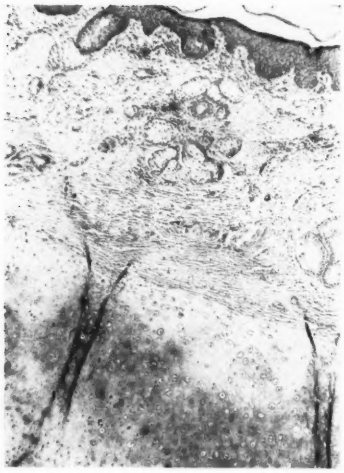


Fig. 2.

Fig. 3.

Fig. 2. Case 1. Roentgenogram following lipiodol injection of the sinus tract. Tract is visualized from the external orifice *a* to approximately 1 centimeter below the external auditory meatus *b*. A large blob of lipiodol fills the external ear *c* presumably run in from the outside.

Fig. 3. Case 1. Scarred draining sinus in the upper portion of the left anterior neck.



a

c

Fig. 4. Photomicrographs of the internal portions of the surgical specimens removed from Case 1 (a), Case 2 (b), and Case 3 (c), each illustrating at various enlargements a tubular tract lined with an inner layer of stratified squamous epithelium with associated dermal sebaceous and sweat glands and hair follicles. Subepidermal focal lymphocytic infiltrations and an outer wall of elastic cartilage are also present.

b

The postoperative course was excellent. There was no evidence of facial paralysis. And, after a short period of occasional, watery discharge from the left ear, the patient remained asymptomatic.

CASE 2. P.H. No. 041750. K.K., a white female, was seen at the age of 1 year for a Vincent's stomatitis which responded to penicillin and gentian violet topical administrations. Three weeks later a swelling appeared in the right upper lateral neck. This required repeated incisions for drainage. Various antibiotics were employed. A tuberculous survey as well as cultures of the discharge were negative.

On January 9, 1951 surgical excision was performed at another hospital. Incision and drainage were required again on March 5, 1951. A chronic sinus persisted.

On May 19, 1951 the patient was operated upon at this hospital. The sinus opening was described in the right upper neck. In the presence of many enlarged, firm, matted, noncaseous lymph nodes a clinical diagnosis of tuberculosis was entertained and a right upper neck dissection was performed.

Postoperatively, the patient's progress was good. But, she returned to the clinic in July 1951 because of recurrent discharge from the indurated operative site. Except for heavy cerumen secretions in the external auditory canals, there were no complaints referable to the ears. Hypertrophied tonsils were evident.

On August 28, 1951 a second operation was performed at this hospital. At this time, it became apparent that the essential lesion was a fistulous tract running from the skin of the neck to the anterior wall of the cartilaginous portion of the external auditory canal. This tract ran above the posterior belly of the digastric muscle, deep to the parotid gland, and superficial to the main trunk of the facial nerve. Methylene blue injected into the skin opening ap-

peared in the external ear. The upper end of the fistulous tract was excised with some of the cartilage of the canal.

Progress was satisfactory postoperatively. A small separation of the skin healed in secondarily. The child was seen on November 12, 1951. The wound was well healed and there were no ear symptoms.

CASE 3. P.H. No. 059870. K.K., a white female, aged 5 years, was first seen by her physician in November 1947 with a history of an acutely inflamed, fluctuant mass in the left neck of approximately 6 months' duration. Following incision and drainage, there were periods of intermittent, spontaneous discharges from this site.

In May 1950 an operation was performed at another hospital where a patent sinus in a cystic swelling was noted. The tract extended upward toward the tonsillar fossa and was not completely removed. Six weeks later the sinus and discharge reappeared. A discharge from the left ear was also observed following this operation.

She was admitted to the Presbyterian Hospital on September 19, 1951. An otolaryngologic consultant reported a slightly thickened, retracted tympanic membrane without evidence of perforation. A finger of tissue extending from the floor of the external auditory canal to the tympanic membrane was also described.

At operation on September 24, 1951 the fistulous tract in the left neck was found to communicate with a cartilaginous outpouching from the external auditory canal. A probe placed into the external portion of the fistulous tract appeared in the external auditory canal approximately 5 millimeters from the left tympanic membrane. The tract ran anterior and superior to the posterior belly of the digastric muscle. The fistulous tract was transected just short of its internal communication with the external auditory canal to avoid injury to the tympanic membrane.

The patient was placed on systemic terramycin and bacitracin topical irrigations in the left auditory canal. She did well postoperatively and was discharged on the sixteenth hospital day. She was followed in the clinic, and on November 14, 1951 the wound was well healed. The ear was free from discharge and the patient completely asymptomatic.

COMMENT

Microscopic examination of the internal portion of the surgical specimens in the 3 reported cases were each characterized by the presence of an inner layer of stratified squamous epithelium with associated dermal sebaceous and sweat glands and hair follicles. A subepidermal layer of focal lymphocytic infiltration and an outer layer of elastic cartilage were also present. These findings are consistent with the ectodermal origin of this portion of the first branchial cleft (Fig. 4).

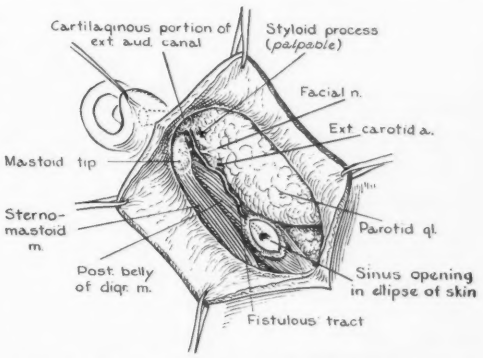


Fig. 5. Diagrammatic illustration of the usual course of the fistulous tract of the first branchial clefts seen at operation. The sinus opens on the neck below the angle of the mandible anterior to the sternocleidomastoid muscle above the level of the hyoid bone. The tract lies anterosuperiorly to the posterior belly of the digastric muscle and the external carotid artery. The anterior relationship of the tract to the facial nerve is not constant. The termination of the tract in the cartilaginous portion of the external auditory canal is shown.

Each of these patients was satisfactorily managed at operation by a single transverse incision from the midline to the tip of the mastoid process anterior to the sternocleidomastoid muscle. An ellipse was included in the skin incision to encircle the external fistulous opening.

The tracts in these 3 anomalies all lay anterior and superior to the posterior belly of the digastric muscle and the carotid artery. This is consistent with the developmental anatomy since this mass of muscle and its nerve supply (facial nerve) is derived from the more inferior second pharyngeal arch (Fig. 5).

The cartilaginous defects in the external auditory canal were not closed. In Case 1, potassium hydroxide solution was applied to this area in an effort to destroy the epithelial remnants.

The correct clinical diagnosis was inferred preoperatively in the first patient. Lipiodol and otolaryngologic examinations were here suggestive of an auditory canal defect. In the second patient, there were no evidences of ear symptomatology, but methylene blue injected into the fistulous tract at operation appeared in the external ear. The third patient was seen shortly after surgical treatment and diagnosis in the second case. A high index of sus-

picion in the presence of an associated draining ear led to the diagnosis at the operating table both by methylene blue injection of the tract and otoscopic examination of the external auditory canal.

SUMMARY

Three cases of congenital anomalies of the first branchial cleft are reported from a total series of 160 branchial cysts and fistulas seen at the Presbyterian Hospital during the past 20 years.

Mistaken diagnoses as to the developmental origin of these defects may result in the performing of inadequate or unnecessary operations.

In the presence of a tentative diagnosis of a branchial defect in the neck, methylene blue or lipiodol visualization of the fistulous tract in association with direct examination of the external auditory canal are useful clinical aids which may lead to the correct diagnosis of congenital anomalies of the first branchial cleft.

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MANAGEMENT OF THROMBOEMBOLIC DISEASE IN SURGICAL PATIENTS

ARTHUR W. ALLEN, M.D., F.A.C.S., Boston, Massachusetts

VENOUS thrombosis, with or without pulmonary embolism, occurs in three main groups of patients: (a) the medically sick, particularly those with cardiovascular disease but also with many other bed-confining disorders; (b) postoperative patients, those following trauma, especially fractures, and after parturition; and (c) otherwise apparently healthy individuals with spontaneous development of the disease. In a large teaching institution such as the Massachusetts General Hospital, this complication is observed in the order of frequency noted above. Medical cases having about a 3 to 1 ratio to those following surgery and trauma, while the spontaneous phenomenon is relatively rare. The ratio of medical versus surgical admissions in this clinic is about 1 to 2.

Since catastrophic sudden death from pulmonary embolism following surgery or injury in a patient who is otherwise making a satisfactory recovery is so impressive, it is understandable that much effort has been directed toward the prevention of this situation. Our experience in this particular group of patients will be given in some detail, with resulting conclusions regarding our present concept of the prevention of thromboses and the treatment of the condition, if it occurs, in the hope of avoiding serious or fatal embolic sequelae. It will be obvious that our endeavors have not been completely successful, but we believe it will be likewise clear that we now have a better understanding of the problem than formerly. We are sure that many deaths from pulmonary embolism have been avoided and that morbidity has been greatly reduced.

Much of the knowledge concerning intravenous clotting is old, but newer approaches to the clinical and pathologic phases of this troublesome complication of illness and injury bring greater hope for its prevention. It is our intention to stress these aspects of this disease and to offer what seems at the moment to be the most logical course to follow. Some of these suggestions will be based on fact, some on experience, and some on conjecture. It remains for further research to clarify and simplify the situation in such a manner that it will be feasible and reasonable to routinize the convalescent period effectively. It is to be admitted that there will always be variations in co-operation of the patients and in the personnel. Also, it appears now that we have no other choice than to subject a major percentage of our patients to a routine, unnecessarily, because we have no reliable scientific formula to help us determine in advance the minority who will develop venous thromboses if left untreated. So far, efforts directed toward selection, although apparently successful in the hands of their sponsors, have not been sufficiently simplified to warrant universal adoption.

In our earlier years we became aware of the value of Pool's suggestions regarding certain general measures for the reduction of thrombosis of the veins in postoperative patients. These were based on sound reasoning and were directed toward maintaining blood flow through the venous system, since it has been long known that stasis in the large veins of the legs was a significant factor in the development of a localized thrombus, from which propagating thrombi were built up in such large segments that when they became detached en masse they were sufficient in size completely to occlude the pulmonary artery. By keeping patients moving, at first passively, then actively, encouraging them to breathe deeply at frequent intervals, avoidance of abdominal binders and tight dressings, blood in the deep veins is kept in motion. Negative pressure in the thorax and muscular activity

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From the Department of Surgery, the Massachusetts General Hospital, Boston.

TABLE I.—MORTALITY FOLLOWING THERAPEUTIC MEASURES IN THROMBOEMBOLIC DISEASE

Surgeon	Year	Measures	No. of cases	No. of deaths from pulmonary embolus	Mortality rate, per cent
Evans	1948	Anticoagulants	184	3	1.6
Cummine	1948	Anticoagulants	89	2	2.2
Murray	1948	Anticoagulants	520	0	0.
Bauer	1950	Anticoagulants	351	3	0.85
Jorpes	1950	Anticoagulants	445	7	1.5
E. V. Allen	1950	Anticoagulants	681	1	0.15
Zilliacus	1951	Anticoagulants	576	3	0.52
M. G. H.	1952–Sept.	Femoral vein interruption	1937	10	0.52

acts together to enhance venous return, and thus the opportunity for clot formation within the veins is diminished. This routine has been continued by us with some modifications and additions to be outlined later. By the use of these measures, Welch and Faxon reported a reduction in postoperative fatal emboli from 3 in 1,000, previously noted by Davis, to about 1 in 800 patients convalescing from major surgical procedures.

Specific measures to reduce morbidity from thrombophlebitis and fatal embolism from phlebothrombosis were adopted as soon as heparin became available for clinical use. This substance was spectacular in its effect, but was tedious to administer and was expensive. There was difficulty in determining the length of time the treatment should be continued, so that recurrence of the clinical manifestations was common. Also, fatal emboli and fatal cerebral hemorrhage occurred during its use. Therefore it is not surprising that we were impressed with Homans' concept of a direct attack on the source of the thrombus by the interruption of the deep veins of the legs.

Our earlier approach to interruption of the femoral veins was cautious and limited to those patients who had a well established thrombophlebitis with repeated infarcts. It occurred to us early in this experience that the procedure might be made more effective if the existing thrombi were removed from the lumen of the veins by suction. On many occasions this was so successful that the rapid recovery of the patient with minimal sequelae made it a routine procedure. If the thrombosis was of long standing and with a large element of inflammation present, the whole of the thrombus could rarely be removed. Without doubt many of these veins again became occluded by thrombi. Often, however, when the thrombus was of recent formation and lightly attached to the intima, it was believed that by removing the clot, recurrence or extension of thrombosis was less likely. Relying on symptoms and signs alone, we soon found that the dangerous loose thrombus was often in the apparently unaffected extremity. Therefore, bilateral femoral vein exploration with thrombectomy and final complete division of the veins became routine. At first our cases were almost limited to those patients who had had sublethal emboli. Gradually, the procedure was extended to those with definite leg signs of thrombosis, and finally to those who revealed only suspected signs and symptoms of thrombosis.

In the first survey of this problem in our hospital, it became apparent that there were certain types of patients who were particularly prone to develop thrombosis and embolism. The aged, those with extensive intra-abdominal cancer, and those with fractures or soft part injuries to the lower extremity were particularly vulnerable. As time progressed we were cognizant of the minimal disturbance to the patient and to his legs if normal superficial femoral veins were interrupted. Therefore, we gradually adopted this procedure as a prophylactic measure in a large group of patients who were considered particularly likely to develop thrombosis if left untreated. This method of prevention reached its peak at about the time dicumarol became dependable, and has gradually been replaced by the use of this drug.

Realizing the dangers of dicumarol, we were cautious in its use. It became obvious to us that it could not be safely used empirically and that some patients were highly sensitive while others were quite resistant to this agent. By using it in small doses on a group of middle aged patients and withholding it from a counterpart group, it was possible to establish its variability in action, its

safety, and its effectiveness. The incidence of thrombosis in the treated group was reduced to 20 per cent of that observed in the controls. We did not dare give this anticoagulant to the aged, the arteriosclerotic, or to those whose operative procedure left a large denuded area. It was also withheld from patients who were bleeding or had a bleeding tendency. In no instance have we used dicumarol without laboratory control. Prothrombin time determinations are tedious, expensive, and often unreliable, but if a chart is kept, the response of any particular patient to the drug can be estimated with reasonable accuracy. In spite of care in the selection of patients, and in dosage, we have on occasion produced troublesome bleeding. This has occurred when the prothrombin level had been reduced to not more than 50 per cent of normal. For this reason, we have not routinely aimed at the 30 per cent of normal, commonly advocated. We have been sure that many patients are protected by small doses of the drug and that there is some definite efficacy from its use when the prothrombin time was only slightly reduced. On the other hand, we are free to admit that we have observed many instances of thrombosis and embolism in our cases and occasionally in patients whose prothrombin level has been kept at around 30 per cent of normal. It is fair to say that none of our patients treated prophylactically with dicumarol have died of embolism. Earlier, we had 2 hemorrhagic deaths that may have been due to dicumarol and must be mentioned for accuracy of the record.

Better use of heparin by intermittent doses has been found effective by several observers. Bauer, Loewe and his associates, and many others prefer this method to dicumarol. It has the advantages of immediate action and the counteraction of bleeding by the use of protamine. Its disadvantages are its cost and the need for repeated venipunctures. We have used it frequently when immediate action is desired, but not as a routine in recent years. Tromexane is now available, appears to be safe, can be given by mouth, and acts quickly. We now more often use this drug in preference to heparin when the effects of early anticoagulants are indicated.

TABLE II.—INCIDENCE OF THERAPEUTIC AND PROPHYLACTIC FEMORAL VEIN INTERRUPTION IN 3,022 CASES

Massachusetts General Hospital
1937 to September 1952

Year	Therapeutic No.	Prophylactic No.	Prophylactic Per cent	Total No.
1937–1942	202	0	0	202
1943	150	15	9	165
1944	208	72	25	280
1945	214	178	45	392
1946	259	289	53	548
1947	227	317	58	544
1948	190	170	47	360
1949	149	30	17	179
1950	136	12	10	148
1951	128	0	0	128
Sept.–1952	74	2	3	76
Total	1937	1085		3022

It is well known that much of the research and conjecture relating to this problem have been directed toward the elements of the blood that have to do with its clotting mechanism. Imbalance of these factors doubtless occurs, thus explanations have been advanced regarding the variations in the number of platelets, the prothrombin time derangements due to the trauma of surgery, and various changes in the many known constituents of the blood that may become inadequate or increased under certain circumstances. The antithrombin alteration has been suspected of being the essential element in the production of venous thrombosis. Ochsner and his coworkers (1) have been able to correct the abnormality of the antithrombin by the use of alpha-tocopherol and calcium. The clinical application is difficult and the effectiveness of this method has not as yet, been corroborated. Ochsner has felt that the almost universal use of chemotherapy and antibiotics may bring about changes in the blood that enhance thrombosis. His reasoning is based on the apparent increase in this complication during the last decade. We also have been aware of this apparent increase in postoperative thromboembolism. We are of the opinion that if this is related to antibiotics and chemotherapy, that it is due to the fact that

TABLE III.—SUMMARY—PROPHYLAXIS

Massachusetts General Hospital
1943 to September 1952

	No. of patients	Deaths from pulmonary embolus No.	Per cent	Deaths from hemorrhage No.	Per cent
Prophylactic vein interruption	1085	6	0.55	0	
Prophylactic dicumarol	1940	0		2	0.10
Prophylactic alpha-tocopherol	153	1	0.65	0	

infection is controlled. Patients now rarely die of shock or infection early in their hospital course, and thus live longer after surgical procedures than formerly, and are, therefore, subject to thrombosis. Furthermore, the average age of our patients has increased at the rate of nearly 5 months each year for the past decades, thus they become gradually more vulnerable to thromboembolism. It seems to us probable that these are valid explanations of the fact that the percentage of fatal embolism in proportion to the number of autopsies at the Massachusetts General Hospital has remained unchanged in the past 20 years, as has been brought out by Roe and Goldthwaithe.

A more recent approach to the problem of venous thrombosis and embolism has been advanced by the physiologist, Drinker. In a personal communication he visualizes the situation as follows:

"*First* as to thrombus origin. It has to be due to a process of simple nature which can occur in anyone. This is why I picked out anoxia of the endothelium, due to interference with blood flow through the venae vasorum. These are small vessels, practically of capillary size, and very easily obstructed. In my opinion, there is nothing the matter with the blood itself in patients with venous thrombi, only a slow blood flow past an area of endothelial breakdown and clot formation in consequence. I do not think that the varied activity which follows getting out of bed is as effective in promoting venous flow as contraction of the leg muscles with the feet in the air, the heart lower than the pelvis, and some degree of increased breathing. Such exercises should be done at least 4 times a day.

"*Second.* I believe there are two situations which must be met, therapeutically. The first of these is the postoperative thrombophlebitis. The fact that it may come very silently—that is, with no local pain—is not surprising, since pain along a vein must be related to blood flow through it and some degree of distention of its walls. These cases in which pulmonary emboli develop with no warning from the site of thrombus origin will always be troublesome. This means that whenever there is a suspicion of slow blood flow, anticoagulant therapy should be given at once.

"*Third.* There is an entire group of cases which occur out of a clear sky, with no prior operation or trouble of any sort. The first evidence in such cases is the sudden onset of pleuritic pain. This means there is a pulmonary embolism, but it does not signal the moment of lodgement of the obstruction, as has been commonly thought. The pain comes when time enough has elapsed to allow the escape of whole blood from the infarcted area through the lung on the pleural surface, where clotting causes sticking and pleuritic pain. This is a wandering sort of pleurisy depending upon the amount and extension of the ooze on to the pleural surface, the coagulability of the blood, and its consequent stickiness. Needless to say, the less the blood is coagulable, the less extensive and vagrant will be the pleurisy."

The first two paragraphs quoted explain certain previously known clinical facets of this complex problem. Based on endothelial breakdown via local anoxia within the vein, we can answer the question of the rare occurrence of thrombosis in the young and its frequency in the aged and depleted patient, by assuming that there may be a rare congenital fault in the venae vasorum in the young and the usual, well known effects of degenerative circulatory disorders in the aged. When we have the stage set by this local fault, it is easy to see that stasis within the vein would enhance clotting and its sequellae.

Although Drinker's explanation of the pleuritic pain following infarct, as given in his third paragraph, is perhaps out of place in this discussion, it is a new concept to me and is included here for your consideration. I had always assumed that the lodgement of the clot was coincident with the onset of lung symptoms. Pain in the chest, often being our first manifestation of thrombosis and embolism, may well follow hours or days after a bland thrombus has developed in the extremity. It is interesting, however, that the infarct is rarely demonstrable by roentgen film until at least 24 hours have elapsed following the sudden onset of pain in the thorax. This may be taken as supporting or negative evidence of Drinker's concept. It seems likely

that careful observation in the future by clinician, roentgenologist, and pathologist may or may not substantiate this thesis. Certainly, there can be no doubt concerning the onset of pleuritic pain as an indication for effective, immediate anticoagulant therapy.

O'Neill, working in Drinker's laboratory, made an outstanding contribution to the knowledge of the blood supply of the veins. He was able to demonstrate the venae vasorum in dogs by a special technique of careful preparation and staining methods. By isolating segments of the veins from the surrounding adventitia in vitro, disintegration of the endothelium was demonstrated. In animals, clot formation at the point of interference with the nutrition of the vein, plus partial obstruction of the vein, was produced regularly if the experiments were carried on from 24 to 50 hours. In only 1 out of 5 preparations of less than 24 hours' duration, thrombosis occurred. O'Neill points out that his procedures are more delicate than the crushing and mechanical disruption of the intima, plus obstruction of the vein used by previous investigators. He is aware that his experiments do not completely reproduce the situation met in human thromboses, but believes that in many clinical cases the stasis in the veins previously handicapped by degenerative circulatory changes, plus anoxia during and after anesthesia, may well be comparable. Although he does not mention it in his report, he has informed me that attempts were made to reproduce the clinical picture in dogs by prolonged anoxia. These first efforts were unsuccessful because he did not have time to learn just how long or to what extent experimental animals would stand anoxia. Furthermore, he examined the jugular and femoral veins in a few old dogs and believes that the femoral veins are less well supplied by their own nutrient blood vessels than are the jugulars. This interesting observation may well turn out to be one of the chief reasons that we see femoral vein thrombosis so frequently while subclavian and axillary thrombophlebitis is rare.

Samuels, Samuels, and Webster (16, 17) have corroborated O'Neill's experiments and introduced new methods of staining the venous endothelium. They have also presented a method of using heparin with toluidine blue in staining the endothelium while preserving and staining the platelets. I have been informed by Dr. Gavin Miller and Dr. Webster that this work will be continued and expanded in the McGill experimental surgical laboratories.

It is to research of this type that we must look for a better understanding of the clinical problem of thromboembolism and its solution. It should not be too difficult to demonstrate the venae vasorum in veins from various parts of the human body in fresh autopsy specimens, as suggested by Linton. If this was carried out in different age and disease groups, it would be very helpful in confirming the thesis of anoxia and segmental endothelial disturbance in its relationship to thrombus formation.

At this time we must make use of what exact knowledge there is available. There can be little doubt that stasis in the deep veins of the legs is an important factor. We cannot repair the blood supply of the veins after it has been damaged by the process of disease, injury, and age. We can, to a great extent, reduce stasis in the leg veins in the majority of surgical patients and in many who are medically ill. Also, we can alter the clotting mechanism of the blood by methods now proved to be effective. With these basic considerations before us, it seems reasonable to institute certain routine measures to prevent thrombosis in the majority of patients who are hospitalized. Since there will occur certain spontaneous thromboses in the otherwise healthy individual, we should, as a secondary consideration, outline the treatment that appears logical at this time for the reduction of morbidity and fatal embolism in this group. All clinics have on their staff, men who take little cognizance of this problem, or who believe that routine prophylaxis is too uncertain, and they will supply a constant source of cases for treatment after the disease process has become well established. Comparable data reveal the fact that constant alertness and routine application of our present knowledge, however cumbersome, pay big dividends in reduced mortality and morbidity.

Preventive measures can be carried out in all adult surgical patients as follows:

1. Preoperative prothrombin time should be recorded.

2. Care should be used in eliminating pressure on the leg veins during the operation.

3. Trauma to large pelvic veins by retractors or during dissection should be avoided.

4. The anesthesiologist should maintain adequate oxygenation at all times.

5. Patients with large superficial varicosities should have their legs bandaged before operation.

6. During long operative procedures, the patient should be placed in some Trendelenburg position at intervals when feasible.

7. Any large vein that is sectioned should be interrupted as near its undamaged parent vein as is possible.

8. Procedures should be accomplished as quickly as is consistent with the problem at hand.

9. Dressings should be lightly applied.

10. The foot of the bed should be elevated on 8 inch blocks unless there is a definite contraindication to this position. This aid to gravity is maintained until the patient is completely ambulatory.

11. The patient is turned from side to side every half hour until awake. Then he is helped to turn and encouraged to breathe deeply at this time.

12. For years we have routinely kept elastic bandages on the legs from foot to tibial tubercle. We are not convinced at this time that this maneuver has been helpful, although recent evidence by the group at the Boston university hospitals seems to support its efficacy. Light weight elastic stockings are more comfortable and easier to keep in place than bandages. We would not dispense with this detail if the patient had superficial varicosities or was particularly lethargic.

13. Passive exercises of the joints and muscles with the legs elevated, one at a time, are carried out by the nurse every 4 hours. As soon as the patient can do these exercises himself and the reason explained to him, he usually will co-operate. Several years ago Gamble recognized the importance of keeping the blood in the leg veins moving, and advocated a bed bicycle on a platform that his patients used regularly while in bed. His results were excellent since this exercise was automatic and probably produced negative pressure in the thorax by increasing the respiratory excursions.

14. Dicumarol, 100 to 300 milligrams, is given by mouth as soon as the patient can take it. The amount depends on the preoperative prothrombin time and the size of the patient. The average first dose is 200 milligrams. Forty-eight hours later, another dose of this drug is given, according to the effect of the first administration on the prothrombin time. Most surgical patients will not receive more than 2 doses of this drug. If, however, it is necessary for any reason to keep the patient in bed, such as occurs in many fracture cases, the drug is continued as indicated by the prothrombin time. In younger adults, the level of 30 per cent of normal may be used. In the older age group, we believe that it is not safe to reduce the prothrombin time below 50 per cent of normal.

15. Early walking is regularly practiced. Leithauser and his associates have made the most significant contribution to this phase of postoperative management. If properly carried out, the efficacy of this type of prevention of venous thrombosis is established. If one is going to depend on this method alone, great attention must be paid to the details. Patients must walk and not sit. Regular shoes must be worn or the enforced walking will cause misleading calf tenderness. Sitting is certainly more conducive to thrombosis in the leg veins than lying, and this is probably the explanation of the controversial reports on early ambulation. In many patients recovering from extensive operations for cancer, in many fractures, severe burns, and other injuries, early ambulation in its effective sense cannot be carried out.

16. In a few of the aged and very decrepit patients, unsuitable for the effective measures outlined, we still use prophylactic superficial vein interruption. This is done preferably at the time it becomes obvious that prolonged bed rest will be necessary. It may be done at the time of hip nailing, or other operative

procedure, or within 48 hours of this event. It should be done routinely at the time of thigh amputations for arteriosclerotic gangrene.

Therapeutic methods after a thrombosis has occurred are varied and depend on the age of the patient, his general condition, and his other disorders.

1. As soon as the diagnosis is established, by infarct to the lung or by definite leg signs, quick-acting anticoagulants should be administered. The prothrombin time and clotting time are determined immediately. Heparin or tromexane may be used for early action, and dicumarol may be given at the same time. At the end of 48 hours, it is usually possible to maintain a safe level of blood coagulability by the use of dicumarol alone

2. If there has been a large embolus or the patient is in the older age group where the danger of reducing the prothrombin time below 50 per cent is evident, then bilateral venotomy, thrombectomy, and interruption of the femoral veins should be done as the first step in the treatment. Anticoagulants can be added 24 hours after this procedure.

3. In patients who continue to have swelling and pain in the legs following anticoagulants or femoral vein interruption, procaine blocks of the lumbar sympathetics, as advocated by Ochsner and DeBakey, are helpful.

4. When a patient has had thrombophlebitis during a long period of bed rest in spite of anticoagulant therapy, one must proceed along one of two lines. We have rarely felt it safe to depend on increasing doses of anticoagulants under these circumstances. Usually this complication occurs in the aged, often with multiple injuries or with concomitant heart disease. We have felt that such a patient had a better chance for early and complete recovery by femoral vein interruption, with a subsequent continuation of anticoagulants.

5. The length of time that patients should be maintained on anticoagulant therapy has been a matter of much question and thought. Since an early report by Miller and Rogers from our clinic, when no case of fatal embolism was observed later than 27 days after the diagnosis of thrombophlebitis was established, we have used this evidence as a sort of guide. Taking into consideration the probable variation between the onset of the actual thrombosis and the clinical diagnosis, we can arrive at an approximation of the time anticoagulants are needed. It is a nuisance to follow prothrombin times outside of the hospital, but we believe that this should be done about 3 times weekly as long as the patient is on the drug. Lilly and Lee have observed several deaths from hemorrhage in patients who have taken dicumarol empirically, but on their physician's orders, over a long period of time.

SUMMARY

The problem of venous thrombosis and pulmonary embolism has been discussed.

Newer concepts concerning the causation of this troublesome malady are recorded.

Routine measures for the prevention of this complication in surgical patients have been outlined.

The logical treatment of thrombosis of the leg veins, with or without infarct, has been given in accordance with our experience in this field.

Further research is needed to simplify the laboratory control necessary at the present time. An easier and more reliable method of selection of patients who may develop thrombophlebitis is desirable.

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CYTOLOGIC STUDIES IN MALIGNANT LESIONS OF THE VAGINA

Study I. Primary Squamous Cell Carcinoma

W. KENNETH CUYLER, Ph.D., LOUISE A. KAUFMANN, B.A., LEONARD PALUMBO, M.D., and BAYARD CARTER, M.D.,
Durham, North Carolina

THE results of cytologic studies in malignant lesions of the vagina from January 1, 1949 through April, 1952, are presented in a series of three reports. Study I concerns primary squamous cell carcinoma, Study II deals with sarcomas, and Study III is on metastatic lesions.

The tumors occurred in 24,095 women who sought gynecologic or obstetric consultation. The patients reported in these studies represent only those who were studied by both cytologic and pathologic examinations and do not represent necessarily the total number of patients with these malignant lesions seen in the department during the time involved. The ratio of gynecologic to obstetric patients was approximately 6 to 1.

Study I is concerned with 13 *primary squamous cell carcinomas*. The clinical and pathologic data on all tumors which were diagnosed and treated as primary squamous vaginal carcinomas have been critically examined. If there was doubt concerning the primary site, the tumor was excluded from this series.

Primary squamous cell carcinoma of the vagina is relatively rare. The 13 comprising this paper represent 1.6 per cent of 804 gynecologic cancers studied by Papanicolaou's technique. The corresponding figures, from our studies, for 36 squamous cell carcinomas of the vulva and for 609 squamous cell carcinomas of the cervix are 4.5 per cent and 75.7 per cent respectively.

From the Department of Obstetrics and Gynecology, Duke University School of Medicine and Hospital.

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Miscellaneous data on the patients who are concerned in this report are presented in Table I.

Eight patients were more than 50 years of age. Nine patients were postmenopausal. The average age of all patients was 57.0 years. The average age of our series of 609 patients who had squamous cell carcinoma of the cervix was 48.0 years.

It is unusual to see this disease in a patient 23 years of age, and it is noteworthy that in Patient 12 the lesion was noticed first during pregnancy.

Pertinent data on symptomatology, the lesions, the histologic character of the tumors, and cytologic studies are correlated in Table II.

Vaginal bleeding in varying amounts was the most common significant symptom. The symptoms were of relatively short duration

TABLE I.—INCIDENTAL DATA

Pt. No.	Age	Race	Parity	Menstrual status
1	83	W	4-0-4	Postmenopausal, 41 years
2	74	W	5-0-5	Postmenopausal, 32 years
3	73	C	13-8-0	Postmenopausal, 18 years
4	73	W	10-6-4	Postmenopausal, 36 years
5	71	W	3-1-2	Postmenopausal, 21 years
6	63	C	3-2-0	Postmenopausal, 15 years
7	53	W	3-1-2	Postmenopausal, 2 years
8	52	W	0-0-0	Postmenopausal, 3 years
9	50	C	1-0-0	Regular periodic bleeding
10	46	W	5-0-5	Regular periodic bleeding
11	42	W	4-1-3	Surg. menop. 20 yrs. prior
12	38	C	3-0-4	Postpartum, 3 weeks
13	23	C	1-0-1	Regular periodic bleeding

TABLE II.—CLINICAL, CYTOLOGIC, AND HISTOLOGIC DATA ON VAGINAL LESIONS

Pt. No. 1st visit	Symptomatology	Clinical description	Cytologic interpretation	Histologic description of tumor
1 8-16-50	Noted "slight growth in birth canal," 1 year ago. Yellowish-white discharge, 1 year	Vascular, polypoid, necrotic	Squamous cell carcinoma	Differentiated
2 4-8-52	Spotting for 2 months. Dysuria	Indurated, 1 by 2 cm.	Squamous cell carcinoma, cervix, ? undifferentiated	Undifferentiated
3 2-10-47	Spotting and dysuria, 2½ months	Indurated, friable, bleeding	Squamous cell carcinoma, cervix	Differentiated
4 8-16-50	Bleeding since pelvic exam., 3 weeks prior	Fungating, friable, bleeding	Squamous cell carcinoma	Intermediate
5 6-21-50	Profuse bleeding day before initial visit to LMD	Friable, ulcerative, necrotic, excavated, indurated, 2 by 3 cm.	Squamous cell carcinoma	Differentiated
6 8-23-51	Recurrent episodes of lower abdominal pain. Burning and irritation of the vagina for 7 months. Pain radiating down both legs for 2 months	Flat, hard, ulcerated, bleeding, 3 by 4 cm. Inguinal nodes enlarged, bilateral	Squamous cell carcinoma	Differentiated
7 5-2-49	Spotting, 3 months. Pressure lower abdomen. Pain radiating down right leg. Dysuria and dyschezia, 1 month. Foul leucorrhea, 2 weeks	Indurated, ulcerated 5 by 5 cm. Inguinal nodes enlarged	Adenocarcinoma, endometrium	Undifferentiated
8 6-25-51	Postcoital bleeding, 1 month prior. Right lower quadrant pain	Ulcerated, crater-like, 2 by 1 cm.	Squamous cell carcinoma, cervix. Resembles adenocarcinoma	Undifferentiated
9 11-7-49	Foul smelling, watery discharge, 6 months prior. Bleeding continuously for 4 mo. Recent pain in left lateral vaginal wall and left labia. Rectovaginal fistula	Ulcerated, necrotic, bleeding	Squamous cell carcinoma?	Differentiated
10 5-12-51	Pain in lower abdomen, spotting and postcoital bleeding, 1 year. Watery discharge. Stress incontinence	Ulcerated, necrotic, crater-like, indurated, fixed	Squamous cell carcinoma	Undifferentiated
11 4-30-51	Watery discharge. No bleeding until pelvic examination	Soft, narrow, friable, granular, movable mass, 1 cm. long	Adenocarcinoma. Resembles squamous carcinoma	Undifferentiated
12 1-29-51	Bled for 4 months prior to delivery on 1-4-51	Lobular, friable, bleeding, pedunculated. Occupying 5 cm. area on wall	Inflammatory process; chronic cervicitis	Undifferentiated
13 10-1-51	Intermenstrual spotting 1 month prior and profuse bleeding 2 weeks prior to initial visit to LMD	Plaque-like infiltrative, indurated	No malignant cells recognized on 4 occasions	Differentiated

but there are no conclusive data on the duration of malignancy prior to diagnosis.

The sites of the 13 lesions were as follows: anterior wall, 3; anterior and lateral walls, 3; lateral walls, 3; posterior wall, 4.

Ten of the 13 patients were referred by their family physicians; 6 came in with a clinical diagnosis of vaginal carcinoma and 4 came in with a pathologic diagnosis already established. Two patients were referred from other departments in this hospital. One patient came in voluntarily because of postmenopausal bleeding.

Six of the carcinomas were differentiated, 6 were undifferentiated, and 1 was intermediate in character.

It has been our practice to use the cytologic interpretation of the first smear preparations (vaginal and cervical) from a patient for statistical purposes, regardless of subsequent cytologic findings. The interpretations listed in Table II, therefore, are the results of the first studies made on the patients involved. The results of concomitant, or closely related, pathologic diagnoses are the criteria for the correctness of the cytologic interpretations (2).

In discussing these interpretations, it should be stated that in the case of Patient 13, the tumor was diagnosed elsewhere and was treated with 8,500 roentgen units prior to her first visit to this clinic. Four concomitant pathologic and cytologic studies made here failed to show residual carcinoma. Therefore this patient is excluded from the series in calculating the error of false negative interpretation.

The single false negative interpretation was made in Patient 12. Cancer cells were not recognized on subsequent studies. All

smear preparations were of good quality. In consideration of the character of the tumor, there should have been an abundance of exfoliated material. Repeated studies of these smears failed to explain this error.

The false negative error in this series, then, is 8.4 per cent. This error in studies of squamous cell carcinoma of the cervix during the period covered is 8.1 per cent. However extenuating the circumstances may have been, 2 of the cancers concerned were missed on pelvic examinations in other clinics in this hospital before the patients were referred to the gynecologic clinic. Fortunately, only 11 and 19 days, respectively, elapsed between the initial examinations and the examinations at which the diagnoses were made.

Although the recognition of malignant cells was correct in 91.6 per cent of the patients, it does not imply that the histologic variety or primary site of the cancer was identified with 91.6 per cent accuracy. The tumors in 2 of the patients were thought to be adenocarcinoma rather than squamous carcinoma. One of these was interpreted unqualifiedly as adenocarcinoma of the endometrium. Some of the malignant elements in the smears from Patient 7 were said to resemble adenocarcinoma. Undifferentiated tumors were found in each of these 3 patients. It is true that atypical squamous cells and well differentiated tumor cells often may be seen in smears containing the cells exfoliated from a markedly anaplastic squamous carcinoma. On the other hand malignant cells which appear to be squamous are often found in smears of adenocarcinoma of the endometrium (1).

It has not been possible in these studies to distinguish cell types in smears of primary squamous cell carcinoma of the vagina from those which commonly characterize squamous cell carcinoma primary in the cervix. However, when malignant cells of endocervical origin appear in smears of squamous carcinoma, it is probable that the primary site of the tumor is in the cervix rather than in the vagina.

SUMMARY

1. This is the first of three reports on malignant lesions of the vagina. Clinical and cytologic data on 13 primary squamous cell carcinomas comprise the first report. Five years and 4 months, January 1, 1947 through April 30, 1952, are covered; 24,095 obstetric and gynecologic patients were examined cytologically.

2. The incidence of primary squamous cell carcinoma of the vagina was 1.6 per cent of all gynecologic cancers that were studied by both cytology and histology.

3. The age range of the 13 patients was 23 to 83 years. The average age was 57.0 years. This was compared to the average age of 48.0 years in 609 patients who had squamous cell carcinoma of the cervix.

4. Nine patients were postmenopausal. Eight patients were white; 5 were colored. One patient was pregnant when the lesion was first noted.

5. Vaginal bleeding in varying amounts was the most common significant symptom.

6. The sites of the lesions were as follows: anterior wall, 3; anterior and lateral walls, 3; lateral walls, 3; posterior wall, 4.

7. The histologic character of the tumor and the cytologic interpretations are tabulated.

8. The reasons for error in interpretation are discussed.

9. The false negative error in cytologic interpretation was 8.4 per cent.

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EDITORIAL

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RADIOIODINE IN THE TREATMENT OF THYROID DISEASE

TEN years have now elapsed since the first announcements that patients with Graves' disease had been successfully treated with radioactive iodine.[1, 2] The radioactive iodine available prior to and during the war was prepared in the cyclotron, a process so expensive that this form of treatment was quite impractical except on a purely investigative level. However, in 1946, the 8 day half-life radioactive isotope of iodine, I^{131}, was made available by the Isotopes Division of the Atomic Energy Commission and many hospitals, clinics, and laboratories undertook studies with it. During this 6 year period ample evidence has been accumulated to demonstrate that: (1) the fate of a tracer dose of radioiodine is of real value in the diagnosis of aberrations in thyroid activity; (2) the hyperthyroidism of Graves' disease can be controlled by adequate treatment; and (3) objective improvement can be brought about in certain selected cases of metastatic cancer of the thyroid by adequate treatment with radioiodine.

Diagnostic tracer studies in various diseases of the thyroid are based on a natural and characteristic avidity of this organ for iodine which is increased in the hyperplastic hyperfunctioning thyroid of Graves' disease and may be increased in certain hyperfunctioning adenomas. This natural avidity for iodine is markedly diminished to absent in patients having myxedema, or in thyroids which have been altered by inflammatory or other destructive disease processes. Some clinics use in vitro measurements over the thyroid at 24 or 48 hour intervals following the administration of a tracer (1 to 100 microcuries) of radioiodine. Others follow the rate of, or total urinary, excretion of radioiodine in 24 or 48 hours. The normal thyroid concentrates between 15 and 40 per cent of a tracer of radioiodine, while the hyperplastic gland of Graves' disease usually concentrates 50 per cent or more of the tracer, and the hypofunctioning gland concentrates less than 15 per cent. Conversely, the urinary excretion of a tracer dose of radioiodine in normals varies between 60 and 80 per cent, whereas the thyrotoxic patient usually excretes less than 30 per cent of a tracer while a myxedematous patient excretes between 75 and 95 per cent of the radioiodine at a much slower rate.

Although the radioiodine tracer technique as a diagnostic test has certain advantages over the basal metabolic rate and the serum protein bound iodine, it is not infallible. For

[1] HERTZ, S., and ROBERTS, A. Application of radioactive iodine in therapy of Graves' disease. (Abstract.) J. Clin. Invest., 1942, 21: 624.

[2] HAMILTON, J. G., and LAWRENCE, J. H. Recent clinical developments in the therapeutic application of radio-phosphorus and radioiron. (Abstract.) J. Clin. Invest., 1942, 21: 624.

example, the hyperplastic thyroid of iodine deficiency, which oftentimes is associated with decreased function, may concentrate maximum amounts of radioiodine. False negative tests or a decreased pickup of radioiodine may occur in the thyroid of a patient with Graves' disease who has received stable iodides or "priodax" for x-ray visualization of the gallbladder, or who has received lipiodol. Likewise, the administration of certain thyroid inhibiting drugs will also interfere with the concentration of radioiodine in the thyroid. Furthermore, this test cannot be used to follow the results of any therapeutic program, although it is of value in determining the effectiveness of certain thyroid inhibiting drugs.

To argue about the relative merits of the I^{131} tracer test versus the serum protein bound iodine or the basal metabolic rate would be folly. The serum protein bound iodine reflects the level of circulating thyroid hormone, the basal metabolic rate reflects the effect of thyroid hormone on the body's rate of metabolism while the tracer technique measures the capacity of a thyroid to concentrate iodine. None of these tests is infallible and all of them should be used as adjuncts to good clinical evaluation of the patient.

The treatment of hyperthyroidism with adequate doses of I^{131} is a very effective method of restoring thyrotoxic patients to euthyroidism within 2 to 4 months. Overtreatment leads to myxedema and undertreatment leaves persistent thyrotoxicosis. The optimal delivered dose of I^{131} has been estimated to vary between 100 and 200 microcuries per gram of thyroid tissue. Obviously, the success then of this form of treatment depends on accurate determination with prior tracer studies of the amount of radioiodine which will be retained in the thyroid and adequate estimation of thyroid size.

Hyperfunctioning adenomas of the thyroid producing hyperthyroidism will respond to treatment with radioiodine but usually require more radioiodine for control.

There have been no significant untoward effects observed in thyrotoxic patients treated with the 8 day half-life radioisotope of iodine, I^{131}. However, time enough to evaluate any late untoward effects has not yet elapsed. Although the development of cancer of the thyroid in patients who had previously been treated with x-ray is extremely uncommon, Hürthle cell carcinomas, some of which metastasized, have been observed in the thyroids of rats subjected to treatment with very large doses of radioactive iodine.[3] In view of these observations and of the well known skin cancers which have developed at the sites of previous radiation, it is commonly held that radioactive iodine should not be administered in the therapy of hyperthyroidism to patients under the age of 45 to 50 years of age, having uncomplicated Graves' disease. This form of treatment can be justified in patients past middle age, or in younger patients whose disease is recurrent or is complicated by severe or progressive exophthalmos or factors which make the patient a poor surgical risk. If, at the end of another decade, we can say that radioiodine in the doses used in the treatment of Graves' disease is not carcinogenic, we might justly adopt a more liberal attitude as concerns this nonsurgical treatment of hyperthyroidism.

The treatment of cancer of the thyroid with radioactive iodine is limited by the fact that cancers of this organ do not possess the natural avidity for iodine so characteristic of normal thyroid tissue. Although 43 per cent of a large series of thyroid cancers have been observed by the autoradiographic technique to

[3] GOLDBERG, R. C., and CHAIKOFF, I. L. Induction of thyroid cancer in the rat by radioactive iodine. Arch. Path., Chic., 1952, 53: 22.

concentrate measurable amounts of radioiodine none of these tumors concentrated more than a small fraction of that retained by the surrounding normal tissue.[4]

It is of importance, however, that more than 50 per cent of patients having cancer of the thyroid metastatic to lungs or to the skeleton, when subjected to total thyroidectomy or destruction of the normal thyroid with radioactive iodine, have assumed an increased capacity to concentrate radioiodine.[5] Following total thyroidectomy, more than 70 per cent of a series of these patients when subjected to prolonged treatment with thiouracil or mercaptoimidazole have assumed a maximum capacity to concentrate radioactive iodine.[6] Thus it has been possible to administer doses of radioactive iodine great enough to produce cancericidal effects without irreversible ill effects to the nonthyroidal tissues. Objective evidence of tumor destruction has been observed in several patients treated in this manner. It is quite likely that such treatment has resulted also in palliation and prolongation of life of certain patients. However, to the knowledge of this writer there are no patients who can be regarded as finally and definitely cured as the result of such treatment. Indeed most cancers of the thyroid even with distant metastases are much less aggressive than cancers arising in other tissues. Mere prolonged survival is inadequate evidence for cure.

The large doses of radioiodine necessary to produce cancericidal effects, even with maximum concentration of the isotope in tumor tissue, usually produce changes in the hematopoietic tissues. To the writer's knowledge, a fatal pancytopenia has been observed in only 1 patient who received several moderately large doses of I^{131} over a period of 18 months. In view of these considerations the writer strongly advocates that the treatment of cancer of the thyroid be limited to patients whose disease cannot be removed surgically and that such treatment be withheld until maximum uptake of the isotope by the tumor has obtained. Finally, the writer[5] advocates that the dose to be given be determined by following the blood levels after administering a test dose. This same method of determining blood levels and adequate investigation of hematopoiesis should be routine following any therapeutic dose large enough to have a cancericidal effect.

Notwithstanding the important practical uses of radioactive iodine discussed, the writer believes that the most significant contributions have come from the basic studies of thyroid physiology made possible with radioactive iodine. It is hoped that such studies may result in knowledge permitting physiologic rather than destructive, i.e., surgical or radiological, treatments of the various thyroid diseases.

RULON W. RAWSON

[4]FITZGERALD, P. J., and FOOTE, F. W., JR. The function of various types of thyroid carcinoma as revealed by the radioautographic demonstration of radioactive iodine (I^{131}). Tr. Am. Ass. Goiter, 1949, p. 167.

[5]RAWSON, R. W., RALL, J. E., and PEACOCK, W. Limitations and indications in the treatment of cancer of the thyroid with radioactive iodine. J. Clin. Endocr., 1951, 11: 1128.

[6]RALL, J. E., MILLER, W. N., FOSTER, C. G., PEACOCK, W. C., and RAWSON, R. W. The use of thiouracil in the treatment of metastatic carcinoma of the thyroid with radioiodine. J. Clin. Endocr., 1951, 11: 1273.

THE SURGEON'S LIBRARY

THE BOOK SHELF

OUT OF THE MOUTHS OF BABES

PAUL R. HAWLEY, M.D., Chicago, Illinois

ONE of the unfortunate paradoxes in the history of medicine is that whereas never before have such competent young surgeons been trained as are being trained today, never before has it been so difficult for them to get started in ethical practice. Teachers of surgery are almost exclusively men of high principle as well as of great ability. The resident in training cannot associate with them for several years without absorbing professional morality along with professional technique.

Scarcely a week passes without the trials and tribulations of a young surgeon seeking a location being brought to the attention of the American College of Surgeons. Rarely, however, is a case so well documented as one is in the letter reproduced hereinafter.

This is a bona fide letter. It is a purely personal letter, the original in longhand, written by a very new surgeon to his former teacher. The writer had not the faintest idea that his letter would ever be seen by other than his preceptor, and his preceptor is not an official of this College. This letter is reproduced with permission. For obvious reasons, names of persons and specific places have been deleted. Here is the letter:

12 September 1952

Dear Doctor . . .

Want first to thank you for all the time you gave me during the past two years. It has meant a lot to me and I do appreciate it very much. I realize how much you had to give up to teach us there at the hospital. You were one of the few on service who made time in your schedule for me.

My wife and I looked around for a while before definitely deciding on . . . but we both like the city a lot.

I've been having trouble getting on the staffs of the hospitals. I put my applications in in July when we passed through for a vacation and so far I'm still not in—except in the county medical society. The applications are being held up in a committee by one person who just doesn't want new surgeons. There are now 51 surgeons which is too many for such a small place. There are several board men here. I think my application will be acted upon in November. I've already lost 2 gallbladders, 2 hernias and one appendectomy. I have not made even one cent since being here. I may have been foolish to have started out on my own instead of with a clinic or a well established person. I'm finding out how rough it really is. I have enough money in stocks and bonds to stick it out for one year or so with no outside income. If I see no improvement I'll look for a salaried position after one year.

I tried to volunteer my services to some of the charity clinics here but they didn't want any new men. Some of the older men even have that tied up tight. I'm not discouraged though. I just sit in the office six days a week and read medical books and journals. Just finished reading a surgical pathology book from cover to cover.

As far as I could determine the American College of Surgeons hasn't made a dent in fee splitting. I visited my friends in Kansas, Oklahoma, Texas and Arkansas. I visited them to find out the possibility of doing their surgery if I started up in their town. All said sure—for 50 per cent of the fee. That was the standard fee and nearly all had board members as the surgeon now. I had a wonderful offer, as far as money goes, in Texas with a group of 5 or 6 doctors. The head doctor wined and dined my wife and me for the afternoon and into the night before he finally told us the set up. What it amounted to was that each of the doctors scheduled their own surgery and told the patient they would do the case; then I would do the surgery. They would collect the fee and give me one half. It would amount to $40,000 for me per year according to him. I would be busy every morning all morning. They have an American Board man coming in from a close town to do about one half of it now. This surgeon is on the teaching staff of a medical school. My wife spoke up and said it didn't sound very ethical to her. She was insulted. I had to laugh at her because she doesn't know that goes on all the time. From her reaction you would have thought the man was planning to rob a bank and wanted me to go in with him. Probably more of the ghost surgery goes on than we know about.

Thanks again for all you did for me.

(Signed)

This letter is not news. Few are naive enough to be surprised by it. Yet it is the most eloquent indictment of a segment of the medical profession that has yet appeared—eloquent because it was not premeditated, and impressive because it so clearly portrays the tragic disillusionment of a

fine young surgeon before he has had his first patient.

We have been informed that a resolution condemning the American College of Surgeons for its war upon unethical practices is to be sought from the House of Delegates of the American Medical Association. We would be surprised if such an effort succeeded. However, we would not be deterred, nor shall we be deterred so long as the situation exists which is described in this letter.

The time is at hand when every man and woman in medical practice must take a position upon this issue. For its part, the American College of Surgeons lines up beside this young surgeon. Will those opposed take an equally open stand? This is most doubtful. Until now they have secluded themselves in the woodwork, crawling out only under cover of darkness.

Edmund Burke once said, "All that is necessary for the triumph of evil is that good men do nothing."

REVIEWS OF NEW BOOKS

EIGHT printings of the first edition, copyright 1944, attest the popularity of the handbook *Physical Foundations of Radiology*.[1] Many chapters have been rewritten, including the one on protection; new chapters on radioactivity, radioactive isotopes, and supervoltage equipment, and new dosage tables for linear radium sources and for x-rays up to half value layers of 8 millimeters of copper are included.

The authors and publishers should be highly commended for bringing this widely used volume up to date. Students in radiology and physicians interested in radioactive isotopes will find this book truly indispensable. ROBERT BURNS LEWIS.

THE volume entitled *A Textbook of Orthopedics*[2] is indeed a worthy addition to the extensive body of American orthopedic knowledge. It recognizes the fact that orthopedics is more than surgery of the bones and joints by including a section on neurology and information on peripheral vascular disorders as they relate to the musculoskeletal system.

The physical characteristics of the book are attractive. The binding is good. The text is clearly printed on paper of excellent quality. The illustrations and roentgenograms are clearly reproduced and are accompanied by descriptive legends. The bibliography and index leave little to be desired. Meticulous attention has been accorded to accurate spelling.

The treatment of the patient as a whole is emphasized. One is impressed by the elaborate charts giving the action, range, origin, and insertion of the muscles including the accessory muscles. Useful hints on the application of plaster casts as well as an excellent discussion of shoes in their relation to orthopedics will be welcomed by the general practitioner and orthopedist alike. The principles of good dynamic posture are enumerated and shown to be not only useful for the physical body in action but as an approach to life itself. Useful advice on operative procedures is to be found in the chapter on anterior poliomyelitis. Fundamental operations in the other orthopedic fields are adequately outlined.

It is natural in a work of this magnitude that all statements will not meet with universal acceptance. An example of this is the tacit acceptance of screw fixation of the lateral spinal articulations and plate-and-screw fixation of the spinous processes in spinal fusion. The reviewer cannot look with favor on these procedures, because he has so frequently had to remove such hardware either because of its ineffectiveness or because of the complications which have developed as a result of its use. Further, the reviewer does not agree that biopsy of a vertebral body is hardly justified; at times it is the only way to make a diagnosis and, therefore, it is most vital in deciding upon treatment and prognosis. One wonders if "plastic cast" (p. 492) should not read "plaster cast"; if "fracture of the clavicle" (p. 566) should not read "fracture of the scapula"; if "platysmographic" (p. 732) should not be "plethysmographic." No mention is made of early operative repair of complete tears of the medial and lateral ligaments of the knee. It is doubtful if early ambulation as advised after removal of knee cartilage shortens convalescence.

The above points have been mentioned, not to be unduly critical but to indicate that no author can completely satisfy everyone who is working in his field.

As previously mentioned, the treatment of vascular and neurologic disorders as they relate to orthopedics will be welcomed by all those who deal with surgery of the extremities. Although operative procedures receive adequate attention, one cannot study this book with care without coming to the realization that orthopedics comprises much more than surgical treatment. It indicates with great clarity that the orthopedist must be an astute clinician and researcher as well as a surgical technician.

Although this volume will be of value to the general practitioner, it will be of most use to one who devotes his full time to disorders of the musculoskeletal system. JOSEPH M. JANES.

THE small brochure *El lactante vomitador (visto por el cirujano)*[3] attacks the problem of the vomiting infant from a challenging viewpoint. The author narrates his personal experiences and conclusions regarding vomiting in the newborn. He believes in exploiting every diagnostic routine and available mechanism. He states that oftentimes simple visual acuity can lead directly to a diagnosis, such as the character of the vomitus, the presence of meconium, esophagobronchial secretion, and the like in the emesis. Each segment of the gastrointestinal tract is scrutinized and emphasis is placed on the value of an x-ray work-up study. The fact that vomiting in the newborn is frequently associated with mal-

[1] PHYSICAL FOUNDATIONS OF RADIOLOGY. By Otto Glasser, Edith H. Quimby, Lauriston S. Taylor, and J. L. Weatherwax. 2nd rev. enl. ed. New York: Paul B. Hoeber, Inc., Medical Book Department of Harper & Brothers, 1952.

[2] A TEXTBOOK OF ORTHOPEDICS; WITH A SECTION ON NEUROLOGY IN ORTHOPEDICS. By M. Beckett Howorth, M.D. In association with Fritz J. Cramer, M.D., A. Wilbur Duryee, M.D., Donovan J. McCune, M.D., J. William Littler, M.D., and Walter A. Thomson, M.D. Philadelphia, London: W. B. Saunders Co., 1952.

[3] EL LACTANTE VOMITADOR (VISTO POR EL CIRUJANO). By Emilio Roviralta. 1st ed. Barcelona: S. A. Horta Ae Impresiones y Ediciones, 1950.

formation, it is stressed that other malformations in distant parts of the body such as equinovarus, congenital subluxation, and similar disorders are present. These may point to the possibility of deformity of the alimentary tract as the cause of the vomiting and should be given first attention in searching for the origin of the vomiting.

The book is written in a rather categorical style, and inasmuch as it narrates personal experiences statements are made which are at variance with the teachings of some of the better known pediatricians throughout the world. Concerning some of these ideas one wonders whether or not their importance is sufficient to raise a point of discussion. As for instance, when it is maintained that many causes co-ordinate to produce vomiting in the infant, the author begs exception and states that the cause is definitely singular. The author brings out the fact that partial gastric ectopia is not a rare situation, in contradistinction to the opinion of other authorities, and devotes 30 pages to demonstrate his tenet.

The book is simply written and deals with topics which may be considered elementary. It covers well, however, the problem of the vomiting infant, its causes, and the treatments recommended. The bibliography is quite thorough and the x-ray illustrations are good. For one interested in pediatrics, this little monograph will prove relaxing and thought-provoking.

STEPHEN A. ZIEMAN.

THE volume *Surgical Forum*[1] containing the contributions to the Forum on Fundamental Surgical Problems of the American College of Surgeons meeting held in San Francisco during November 1951, contains a wealth of information of both an experimental and clinical nature. Most of the original thought and laboratory investigation carried on by the younger surgeons of America are presented in concise form.

In the section on lungs and esophagus, it is suggested that the use of streptokinase during the early postoperative period following lung resection in dogs does not interfere with the healing process of either the bronchial stump or the ligated vessels when the procedure is properly performed. In addition, the section on lungs and esophagus contains papers dealing with the treatment of pulmonary emphysema, the experimental study of the repair of tracheal defects with fascia and tantalum mesh, the early postoperative pulmonary function in thoracic surgery patients and the reconstruction of the tracheobronchial tree with resection of the carina.

The section on the stomach and spleen gives several studies regarding the etiology and treatment of duodenal ulcer. Gastric physiology is studied by means of secretory responses to banthine and atropine. The effect of radiation from radioactive iodine on gastric secretion is likewise presented. Several papers are concerned with the substitution of a segment of the colon or the ileocolon to replace the stomach as a food pouch after total gastrectomy.

The section on the liver and portal system contains several excellent articles on the study of the hepatic circulation and the surgical anatomy of the portal system. Studies of the physiological effect of hepatic artery and portal vein ligation and the results of perfusion studies and observations on patients at operation are presented. Several investigations on the effects and results of portacaval anastomoses are included.

The application of surgery to congenital and acquired heart disease represents a significant segment of this volume. This is easily explained by the recent popularity and emphasis on such problems. The fundamental surgical research being accomplished in this regard is exemplified by the large number of articles dealing with this subject included within this volume. The repair of interauricular septal defects, the results obtained from valvulotomy for mitral stenosis, and the studies and results of the use of extracorporeal circulation for operations on the open heart are presented.

Other experimental, as well as clinical, investigations of the urogenital tract, the brain and spinal cord, orthopedic problems as well as the endocrine systems and body fluids and electrolytes, blood volume and shock, are given.

There is no doubt that this volume of papers on fundamental surgical problems presents some of the original thinking and investigations by the outstanding surgeons of the United States. The papers of necessity must be published in brief form so that their content is concise as well as precise.

ORVILLE F. GRIMES.

A RATHER unique presentation of the subject material in outline form is used in the volume entitled *Correlative Cardiology; an Integration of Cardiac Function and the Management of Cardiac Disease.*[2] The authors have attempted to cover the entire field of normal and abnormal cardiac physiology and pathology including electrocardiography and roentgenology in 500 pages, a substantial task. Some students, undoubtedly, will be interested in the concise descriptive outlines and to many the book will have little appeal. The outline method necessitates brevity and a tendency to dogmatism.

There are many excellent diagrams and charts to amplify the didactic outlines. The subject material is conventional and modern. There is a good index and the printing and binding are well done.

CHAUNCEY C. MAHER.

[1] SURGICAL FORUM; PROCEEDINGS OF THE FORUM SESSIONS, THIRTY-SEVENTH CLINICAL CONGRESS OF THE AMERICAN COLLEGE OF SURGEONS, SAN FRANCISCO, CALIFORNIA, NOVEMBER, 1951. Surgical Forum Committee: Owen H. Wangensteen, M.D., F.A.C.S., Minneapolis Chairman, Warren H. Cole, M.D., F.A.C.S., Chicago, Robert E. Gross, M.D., F.A.C.S., Boston, Michael L. Mason, M.D., F.A.C.S., Chicago, Carl A. Moyer, M.D., F.A.C.S., Dallas, I. S. Ravdin, M.D., F.A.C.S., Philadelphia. Philadelphia, London: W. B. Saunders Co., 1952.

[2] CORRELATIVE CARDIOLOGY; AN INTEGRATION OF CARDIAC FUNCTION AND THE MANAGEMENT OF CARDIAC DISEASE. By Carl F. Shaffer, M.D., F.A.C.P., and Don W. Chapman, M.D., F.A.C.P. Philadelphia, London: W. B. Saunders Co., 1952.

THE fourth part, in a series of 5 volumes on *Emergency Surgery*,[1] considers emergency conditions of traumatic and inflammatory nature of the head, neck, thorax, spine, blood vessels, joints, tendons, and nerves. Most of this volume is devoted to treatment and much of the discussion is from the authors' experience. Only brief consideration is given to diagnosis and postoperative care.

The text is well written and is enhanced by frequent additions of brief case summaries and well chosen illustrations. Text material is also supported by a brief though inclusive bibliography.

This volume should be welcomed by the student and the practicing physician alike, who will appreciate its lucidness and lack of encyclopedic detail.

W. HARRISON MEHN.

THE diseases of the esophagus have been discussed in terms of their morphologic and physiologic behavior in the excellent book, *The Esophagus and Its Diseases*,[2] by Lieutenant Colonel Eddy D. Palmer of the Medical Corps of the United States Army, and Chief of the gastrointestinal section of the Walter Reed Army Hospital. Dr. Eddy has accomplished his purpose and has given us an exceedingly well written and well illustrated account of the esophagus, its anatomy, physiology, and pathology. As the author points out, the technical advances of the esophageal surgeon are fast outstripping clinical understanding of the organ and its diseases. In view of this fact, the reviewer cannot help but speculate on the advantages of collaboration between an internist and a surgeon in a book of this kind. The author's evident wide experience in this field has been supplemented by an exhaustive study of the literature, and an excellent bibliography has been provided for each chapter. It is doubtless due to this fact that the surgical principles underlying treatment are sound and practical. The author is to be commended for having given us a book that will be of undoubted service to specialists in gastroenterology and otolaryngology, as well as surgeons interested in general surgery and thoracic surgery.

LESTER R. DRAGSTEDT.

NEUROLOGIC surgery, as a growing surgical speciality, has needed a reference atlas for various procedure descriptions. To refresh one's mind on neurosurgical procedures, one has had to rely on the various monographs. This, of course, is the ideal way to review a procedure, but it is not always possible, nor is it always feasible. Gurdjian and Webster have attempted in their volume *Operative Neurosurgery with Emphasis on Procedures*[3] to meet the needs of the neurosurgeon and of the general surgeon required to do an occasional neurosurgical operation.

The book was read and reread with mixed reactions by the reviewer. A preliminary survey leaves one with the impression that it is incomplete. However, critical review finds that this is not the case. A few of the more uncommon procedures are not described, but this cannot be called a fault. One having to do a neurosurgical procedure for the first or infrequent times should consult the original monograph and thoroughly familiarize himself with the anatomic and technical details beyond those that could be expected in an operative surgery text.

The written descriptions are clear, concise, and phrased to flow in easy smooth reading. The drawings are generally schematic and diagrammatic and must be carefully studied with the written description for understanding. The classic and more easily understood anatomic colored drawings are missing. The absence of color contrast hampers easy recognition and understanding. However, this forces one to study the text with greater detail and probably the end result is an improvement.

The authors, because of their experience in traumatic lesions might have been a bit more descriptive in both their verbal and pictorial descriptions of surgery of the traumatized nervous system. This particular part of the book is one which probably will be read and followed more widely by the general surgeon than any other chapter and should be the most descriptive and the easiest understood with the least knowledge of neurologic anatomy and physiology needed. The chapter on the sympathetic system and on the peripheral nerves would be improved by more realistic drawings. The inclusion of caricature type of facial drawings detracts instead of adds to the character of the book and certainly contributes nothing toward clearer understanding and recognition.

The material division of the volume into 4 parts, namely, head, spine, sympathetic nervous system, and peripheral nerves, is well choosen. The historical prelude to each chapter, while brief, has added to the interest of the book. Also, inclusion of preliminary considerations, including diagnostic aids, anesthesia, preoperative and postoperative care, technical consideration and descriptive footnotes are excellent. From the makeup standpoint of the book, criticism of the volume could be directed toward overcrowding of some of the drawings on certain pages, particularly that dealing with the exposure of the brachial plexus on page 387. This is confusing and very difficult to understand, even with careful reading of the script. As before stated, the schematic and occasional caricature type of drawing will be annoying to some people. The size of the book, the choice of paper and print are exceptionally good. The publisher is to be congratulated for his share in making this book readable. The bibliography is extensive and inclusive, and careful study of it did not reveal any mistakes. Only

[1] EMERGENCY SURGERY. Part IV. By Hamilton Bailey, F.R.C.S. (Eng.), F.A.C.S., F.I.C.S., F.R.S.E. Assisted by Norman M. Matheson. M.B., Ch. B., M.R.C.P. (Lond.), F.R.C.S. (Eng.), F.A.C.S. 6th ed. Baltimore: The Williams & Wilkins Co., 1952.

[2] THE ESOPHAGUS AND ITS DISEASES. By Eddy D. Palmer, M.D., F.A.C.P. New York: Paul B. Hoeber, Inc., Medical Book Department of Harper & Bros., 1952.

[3] OPERATIVE NEUROSURGERY WITH EMPHASIS ON PROCEDURES IN TRAUMA. By Elisha Stephens Gurdjian, M.D., and John E. Webster, M.D. Baltimore: The Williams & Wilkins Co., 1952.

one error was found in the script, that of giving the wrong page number for a drawing reference.

In conclusion, this book is recommended by the reviewer as a valuable addition to each and every medical library and a must for the general surgeon, who of necessity, occasionally treats traumatic wounds of the nervous system.

DAVID CLEVELAND.

BOOKS RECEIVED

Books received are acknowledged in this department, and such acknowledgment must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interests of our readers and as space permits.

LEHRBUCH DER ROENTGENOLOGISCHEN DIFFERENTIALDIAGNOSTIK; ERKRANKUNGEN DER BRUSTORGANE. By Werner Teschdendorf. Vol. 1. Stuttgart: Georg Thieme, 1952.

IL CUORE ARTIFICIALE. By E. Tosatti. Milano: Istituto Sieroterapico Milanese S. Belfanti, 1951.

LA COLANGIOGRAFIA LAPAROSCOPICA (COLANGIOGRAFIA NO QUIRURGICA). By M. Royer. Buenos Aires: Libreria "El Ateneo" Editorial, 1952.

THE FOOT. By Norman C. Lake, M.D., M.S., D.Sc. (Lond.), F.R.C.S. (Eng.). 4th ed. London: Baillière, Tindall and Cox, 1952.

THE MECHANISMS OF DISEASE; A STUDY OF THE AUTONOMIC NERVOUS SYSTEM, THE ENDOCRINE SYSTEM AND THE ELECTROLYTES IN THEIR RELATIONSHIP TO CLINICAL MEDICINE. By Joseph Stambul, M.D. Foreword by George Morris Piersol, B.S., M.D. New York: Froben Press, Inc., 1952.

MEDICAL BIOGRAPHIES; THE AILMENTS OF THIRTY-THREE FAMOUS PERSONS. By Philip Marshall Dale, M.D. 1st ed. Norman, Okla.: University of Oklahoma Press, 1952.

THE LOW FAT DIET COOK BOOK. By Dorothy Myers Hildreth and Eugene A. Hildreth, M.D. Introduction by Francis C. Wood, M.D. New York: Medical Research Press, 1952.

ACUTE PERIPHERAL ARTERIAL OCCLUSION. PUBLICATION NO. 141, AMERICAN LECTURE SERIES. A MONOGRAPH IN AMERICAN LECTURES IN CIRCULATION. By William D. Holden, M.D. Edited by Irvine H. Page, M.D., and A. C. Corcoran, M.D. Springfield, Ill.: Charles C Thomas, 1952.

NOUVELLE PRATIQUE CHIRURGICALE ILLUSTRÉE. By Jean Quénu. Part 6. Paris: G. Doin et Cie, 1952.

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GYNAEKOLOGISCHE STRAHLENTHERAPIE; INDIKATIONSSTELLUNG, METHODIK UND AERZTLICHE BETRAUUNG. By Dr. Med. Richard Kurt Kepp. With a foreword by Prof. Dr. Heinrich Martius. Stuttgart: Georg Thieme, 1952.

DIE FRUEHDIAGNOSE DES UTERUSCARCINOMS; HISTOLOGIE, KOLPOSKOPIE, CYTOLOGIE, BIOCHEMISCHE METHODEN. By Prof. Dr. Med. Hans Limburg. Stuttgart: Georg Thieme, 1952.

PHOTOGRAPHY THROUGH THE MICROSCOPE. 1st ed. Rochester, New York: Eastman Kodak Co., 1952.

ROENTGENDIAGNOSTICS. By H. R. Schinz, W. E. Baensch, E. Friedl, and E. Uehlinger. First American Edition (Based on the Fifth German Edition). English translation arranged and edited by James T. Case, M.D., D.M.R.E. Vol. 2. New York: Grune & Stratton, 1952.

MANUAL OF UPPER EXTREMITY PROSTHETICS. By the Staff, Artificial Limbs Project, Department of Engineering, University of California, Los Angeles, California. Edited by R. Deane Aylesworth. Washington: National Research Council, 1952.

ROENTGENUROSKOPIE; NIERENBECKEN UND -KELCHE, HARNLEITER, BLASE, HARNROEHRE. By Dr. Med. Habil. G. W. Günther. Stuttgart: Georg Thieme, 1952.

A TEXTBOOK OF GYNAECOLOGICAL SURGERY. By Victor Bonney, M.S., M.D., B.Sc.(Lond.), F.R.C.S.(Eng.), Hon.-F.R.A.C.S., Hon.F.R.C.O.G., M.R.C.P.(Lond.). 6th ed. New York: Paul B. Hoeber, Inc., Medical Book Department of Harper & Brothers, 1953.

OFFICE PSYCHIATRY; THE MANAGEMENT OF THE EMOTIONALLY AND MENTALLY DISTURBED PATIENT. By Louis G. Moench, M.D. Chicago: The Year Book Publishers, Inc., 1952.

GRUNDSAETZLICHES ZUR PROPHYLAXE DES MUTTERMUNDKREBSES. By Dr. Robert Ganse. Leipzig: Georg Thieme, 1952.

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DISEASES OF METABOLISM; DETAILED METHODS OF DIAGNOSIS AND TREATMENT. Edited by Garfield G. Duncan, M.D. With contributions by various editors. 3rd ed. Philadelphia, London: W. B. Saunders Co., 1952.

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